Sediments Part 1: Policy, Guidance, and Characterization

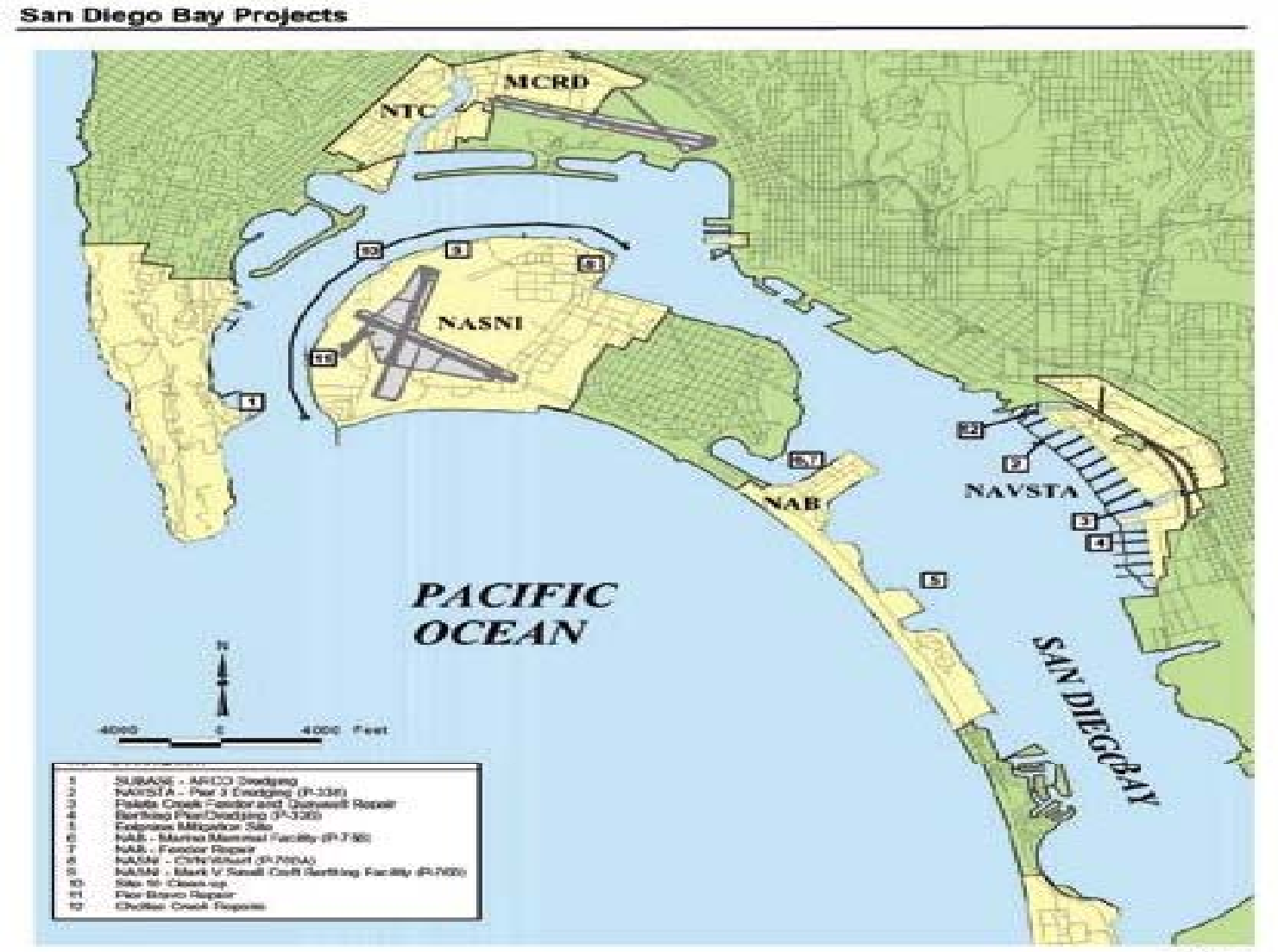
NAVFAC

Overview

- Sediment Issues
- Definitions and Ecosystem Overview
- Chief of Naval Operations (CNO) Sediment Policy
- Introduction to Naval Facilities Engineering Command (NAVFAC) Sediment Implementation Guide
- Sediment Site Characterization
- Basics of Remaining Sediment Guide
- References and Points of Contact (POCs)

Source: SSC San Diego

Typical Navy Installations



Source: SWDIV

Sediment Issues

- Complexity of assessing and managing contaminated sediment sites
  - Dynamic ecosystem, contaminant mobility, multiple exposure pathways
  - Technical issues; state-of-the-science
  - Regulatory trends
- Potential economic ramifications
- Historical lack of consistency and data quality in sediment investigations

Magnitude of the Problem

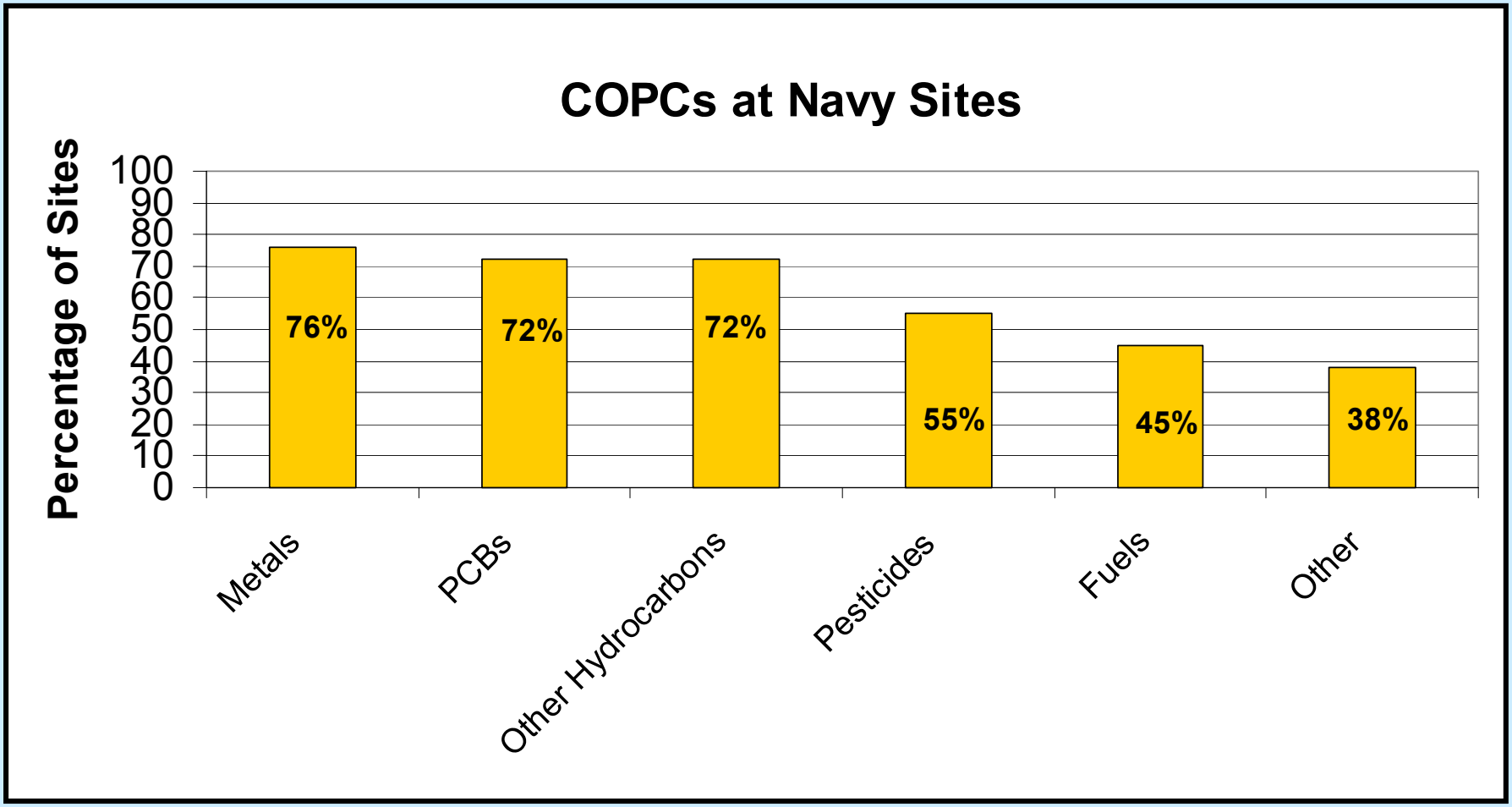
- U.S. EPA 1997 Report to Congress
  - 6 to 12% of U.S. sediment contaminated (~72 to 144 MCY)
  - 10% marine or estuary sediment lethal to aquatic life
  - 5% of U.S. watersheds have health-threatening sediments
- 2,800 Fish Advisories in the U.S.
  - 71% coastal waters in lower 48 states
  - 92% Atlantic, 100% Gulf
  - Major contaminants: mercury, PCBs, dioxin, and DDT
  - (U.S. EPA 2001; EPA/823/F/01/010)

Picture modified from
http://www.epa.gov/waterscience/fish/forum/pdfs/NY_sigRE.pdf

Magnitude of the Problem

- For Navy alone, contaminated sediment sites cleanup cost-to-complete estimated at $1.3B for 223 sites
- Typical chemicals in sediments at Navy sites include heavy and trace metals, PCBs, chlorinated pesticides, PAHs, and organotins
- Constituents of potential concern (COPCs) in sediments based on Naval Facilities survey conducted c.1993
- 94% of Navy survey responses reported at least one COPC in sediments; hotspots and mixed contaminants common

Magnitude of the Problem



Comparisons of Aquatic and Terrestrial Site Investigations

COPC Behavior	Terrestrial Groundwater	Aquatic
COPC Sources	• Point sources - Above-ground spills - Underground storage - NAPLs	• Point (e.g. outfalls) and non-point (e.g. runoff) • Secondary sources
Major COPC Types	• Various soluble, insoluble, and sparingly soluble - TPH & petroleum - Chlorinated solvents - Energetic compounds - Metals - PAH	• Persistent non-volatile and insoluble compounds -PAH -PCBs -Metals
COPC Transport	• Groundwater transport from point source • Predictable concentration gradient away from source	• Sediment transport (sorbed) • Deposition and resuspension • Porewater transport • COPCs often randomly redistributed, with vertical gradient profiles

Comparisons of Aquatic and Terrestrial Site Investigations

COPC Behavior	Terrestrial Groundwater	Aquatic
Ecological Receptors	• Site boundaries usually well defined • Significant human disturbance common • Large literature database regarding food-web interactions, exposure parameters, and toxicological effects	• Site boundaries often difficult to identify • May have lower degree of human disturbance but higher degree of natural disturbance • Literature on exposure parameters and toxicological effects is limited
Human Receptors	• Multiple direct and indirect exposure pathways typically considered - ingestion - inhalation - dermal contact	• Generally limited to indirect pathways - Fish and shellfish ingestion

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Definitions
(1 of 4)

- Sediment
  - Material, such as sand, silt, or clay, suspended in or settled on the bottom of a water body (U.S. EPA, 1998).
- Estuarine
  - An area where a river empties into an ocean; results in a mixture of saltwater and freshwater.
  - Salinity is 0.5 ppt to 30 ppt.
- Marine
  - Of or relating to the sea.
  - Salinity >30.0 ppt.
- Freshwater
  - Water containing an insignificant amount of salts, such as in inland rivers and lakes.
  - Salinity <0.5 ppt.

Definitions
(2 of 4)

- Benthic Region
  - The bottom layer of a body of water.
- Benthic Organisms
  - Organisms that live in or on the bottom of a body of water, including the ocean floor or river bed.
- Epibenthic
  - Animals (epifaunal) or plants (epifloral) that live on the surface floor of the ocean or other water body.
- Infauna
  - Organisms that live within the surface sediments such as clams and worms.

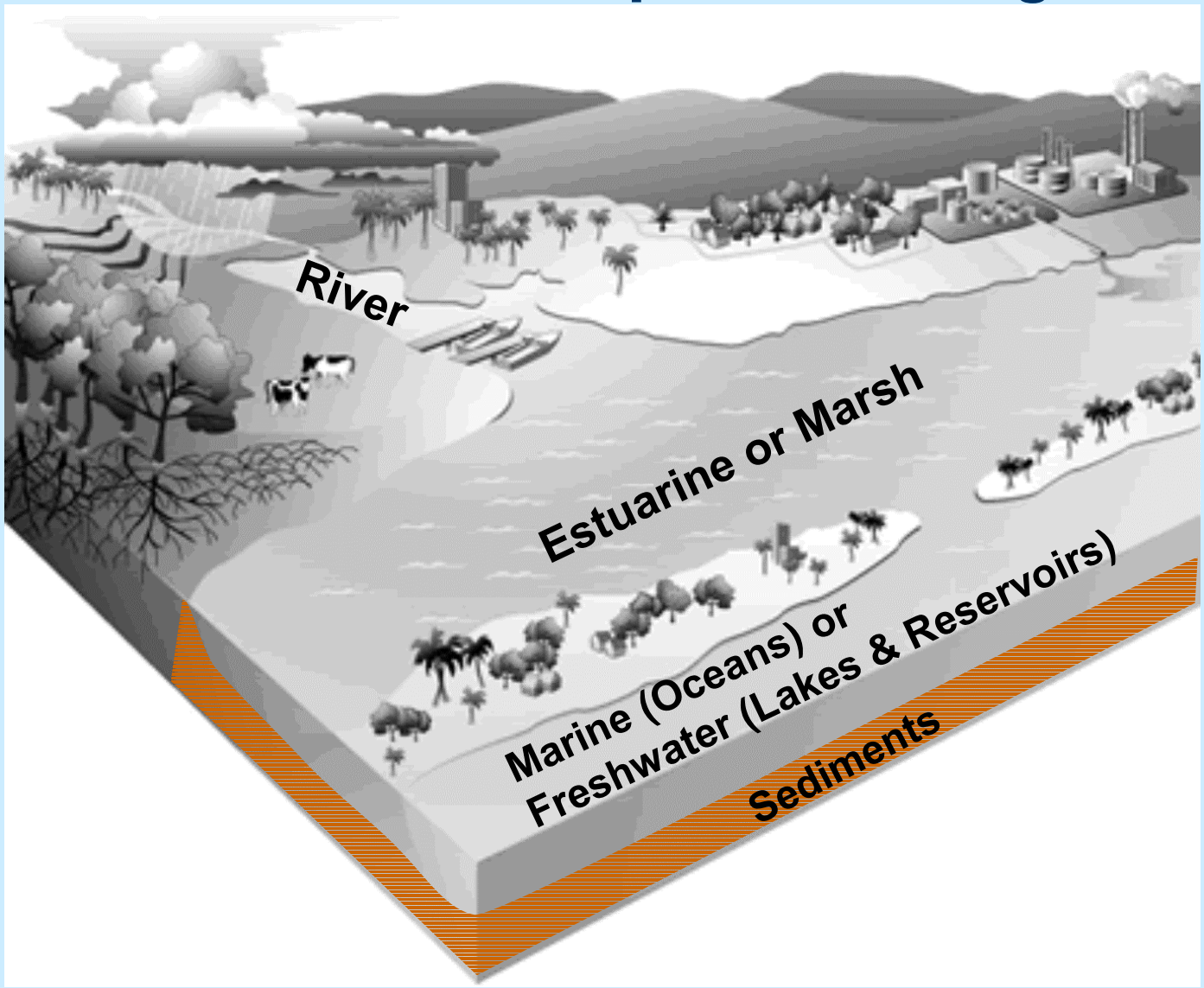
Definitions
(3 of 4)

- Conceptual Site Model (CSM)
  - A written or pictorial description of the elements of a site, including assumptions about exposure and effect. The CSM identifies known or suspected contaminant sources, release and transport mechanisms, exposure routes, and receptors.
- Weight of Evidence (WOE)
  - Quantitative approach to ranking sediment risk (based on concentration, toxicity, and other factors).
- Non-Navy Source
  - Refers to a source of contamination that is not a result of Navy or Marine Corps operations. An entity (industrial plant, private or public sector, etc.) not operated by the Navy.

Definitions
(4 of 4)

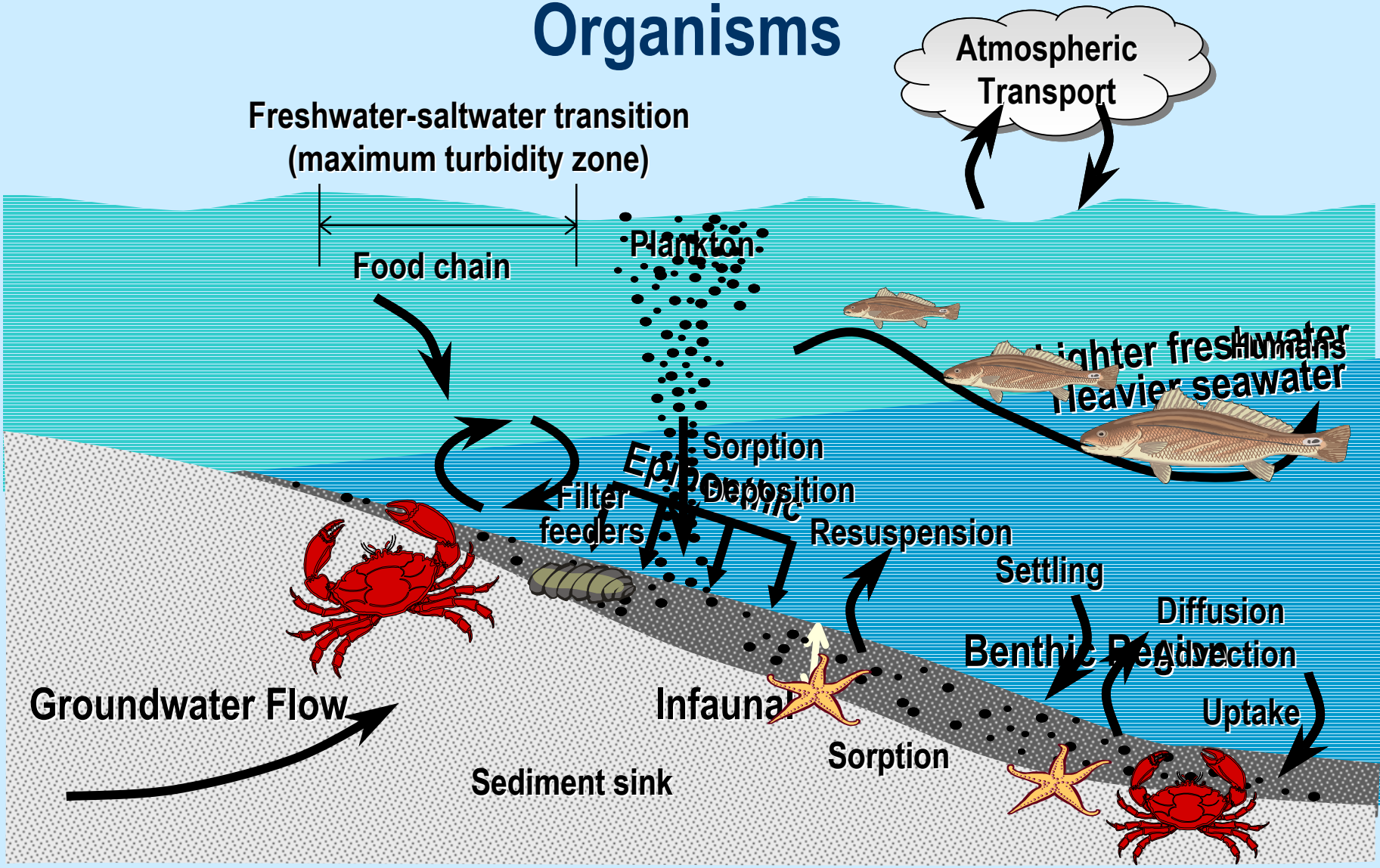
- Watershed Contaminant Sources Document (WCSD)
  - A summary report (2 to 10 pages) on the potential for both Navy and non-Navy sources to have contaminated sediment in the water body adjacent to Navy property. The WCSD briefly identifies potential contaminant sources, releases, transport mechanisms, exposure routes, and receptors from Navy and non-Navy sources. The WCSD should include a pictorial Conceptual Site Model. The purpose of this WCSD is to document the existence of other parties who have impacted the sediments. This brief report should be provided to the appropriate regulator.

Plan View of Aquatic Setting



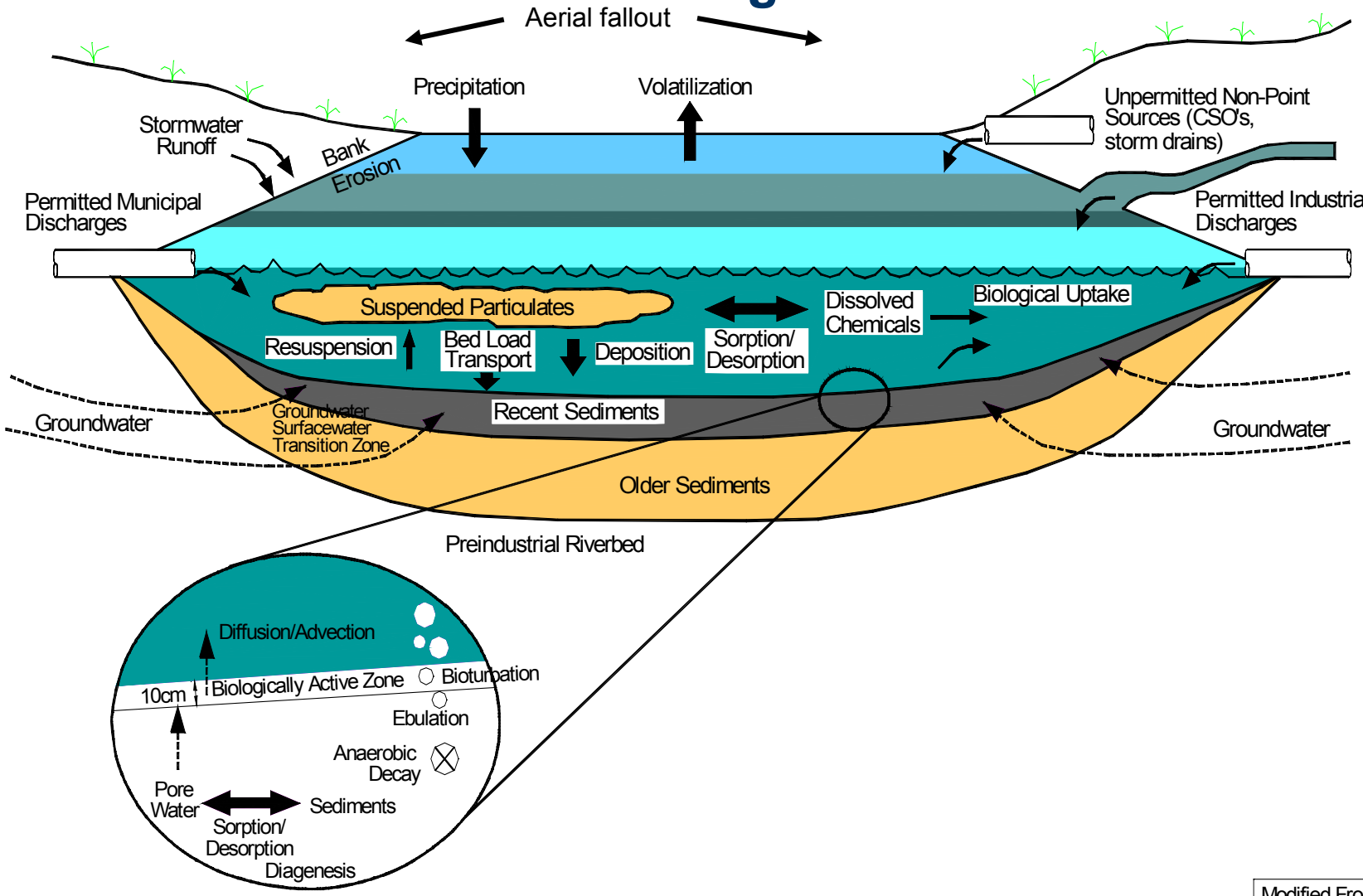
Modified from http://www.epa.gov/owow/oceans/factsheets/fact5.html

Profile of Aquatic Setting with Biological Organisms



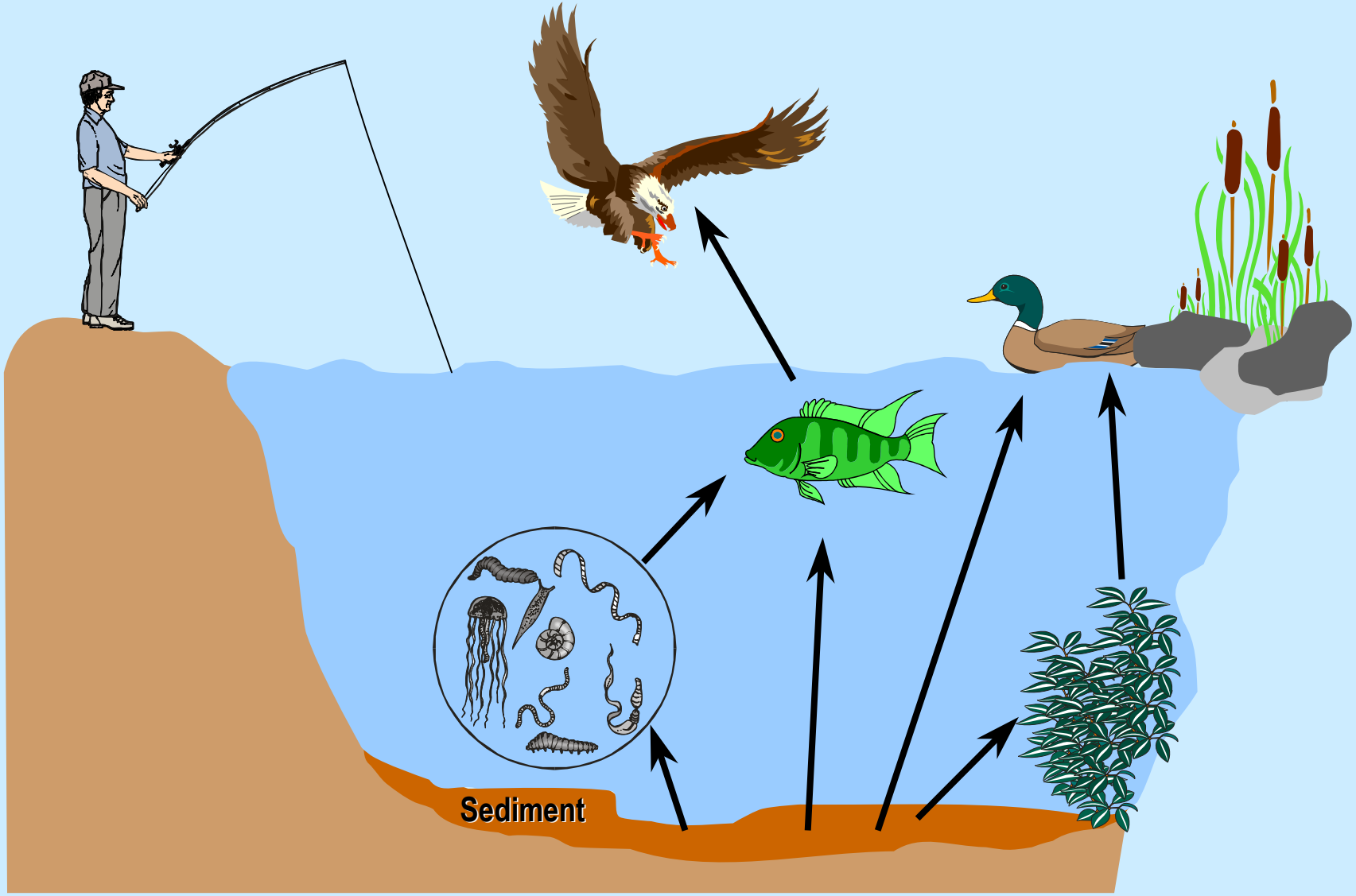
Modified from U.S. EPA, 1987

Conceptual Schematic
Processes Effecting Sediments



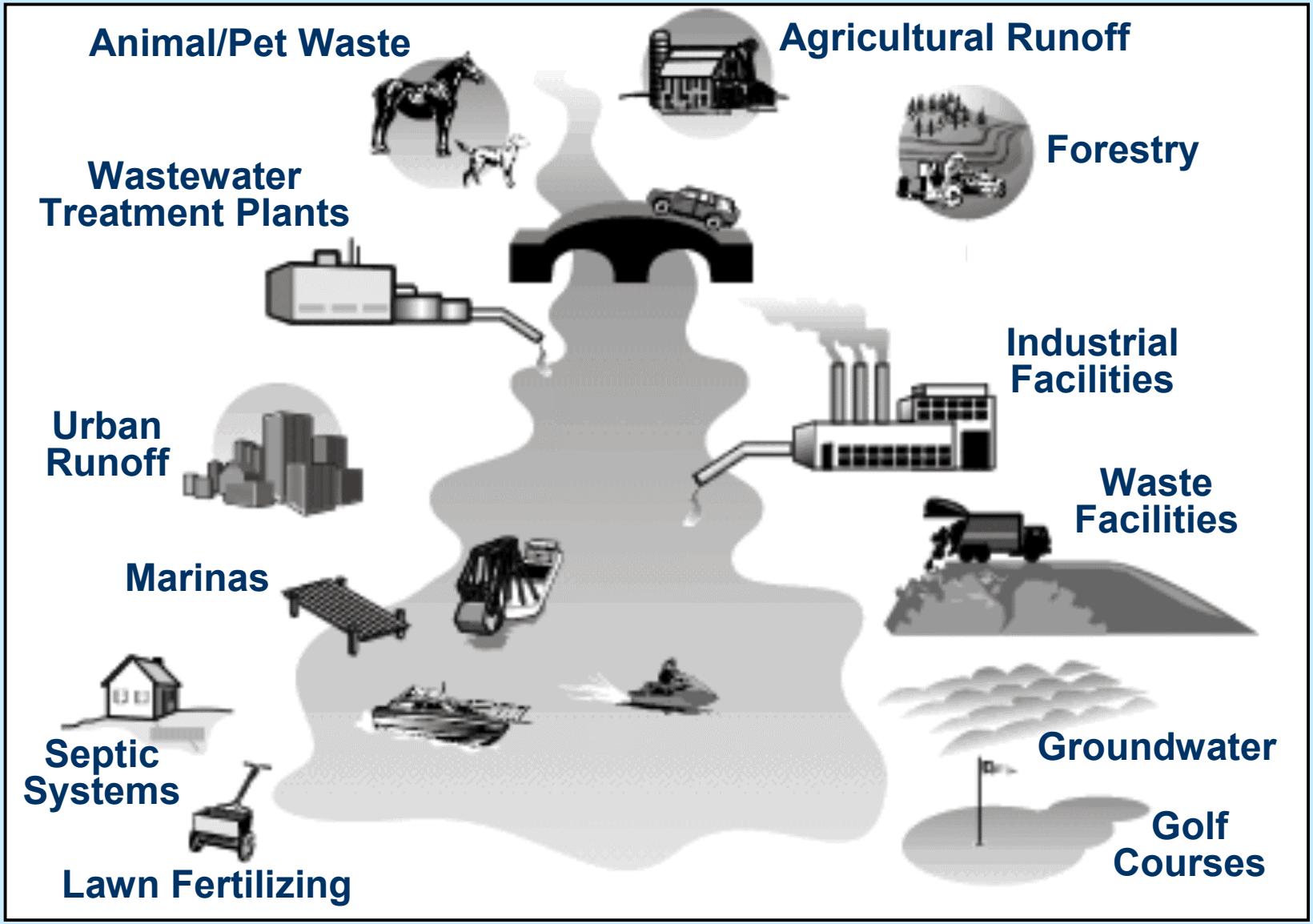
Modified From Exponent 1997

Biological Food Web



Source: Battelle

Sediment Pollution Sources



Modified from U.S. EPA, 1987

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  - Policy Statements
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- References and POCs

DEPARTMENT OF THE NAVY
OFFICE OF THECHIEF OF NAVAL OPERATIONS
2000 NAVY PENTAGON
WASHINGTON DC 20350-2000

IN REPLY REFER TO

5090
Ser N453E/2U589601
08 FEB 2002

From: Chief of Naval Operations
To: Commander, Naval Facilities Engineering Command

Subj: POLICY ON SEDIMENT SITE INVESTIGATION AND RESPONSE ACTION

End: (1) Navy/Marine Corps Installation Restoration Policy on Sediment Investigations and Response Actions

1. Enclosure (1) is provided in response to concerns received from the field pertaining to investigation and clean up of contaminated sediments. The policy specifies that the source must be identified and controlled before cleanup, the cleanup must be risk-based and have site-specific cleanup goals, and the monitoring criteria for any monitoring plan must be established before the first sample is collected.

2. Enclosure (1) has been coordinated with the Marine Corps. For further information or questions please contact Wanda L. Holmes of my staff at (703) 604-5420 or DSN 664-5420 or email holmes.wanda@hq.navy.mil.

WILLIAM G. MATTHEIS
Deputy Director, Environmental Protection, Safety and Occupational Health Division

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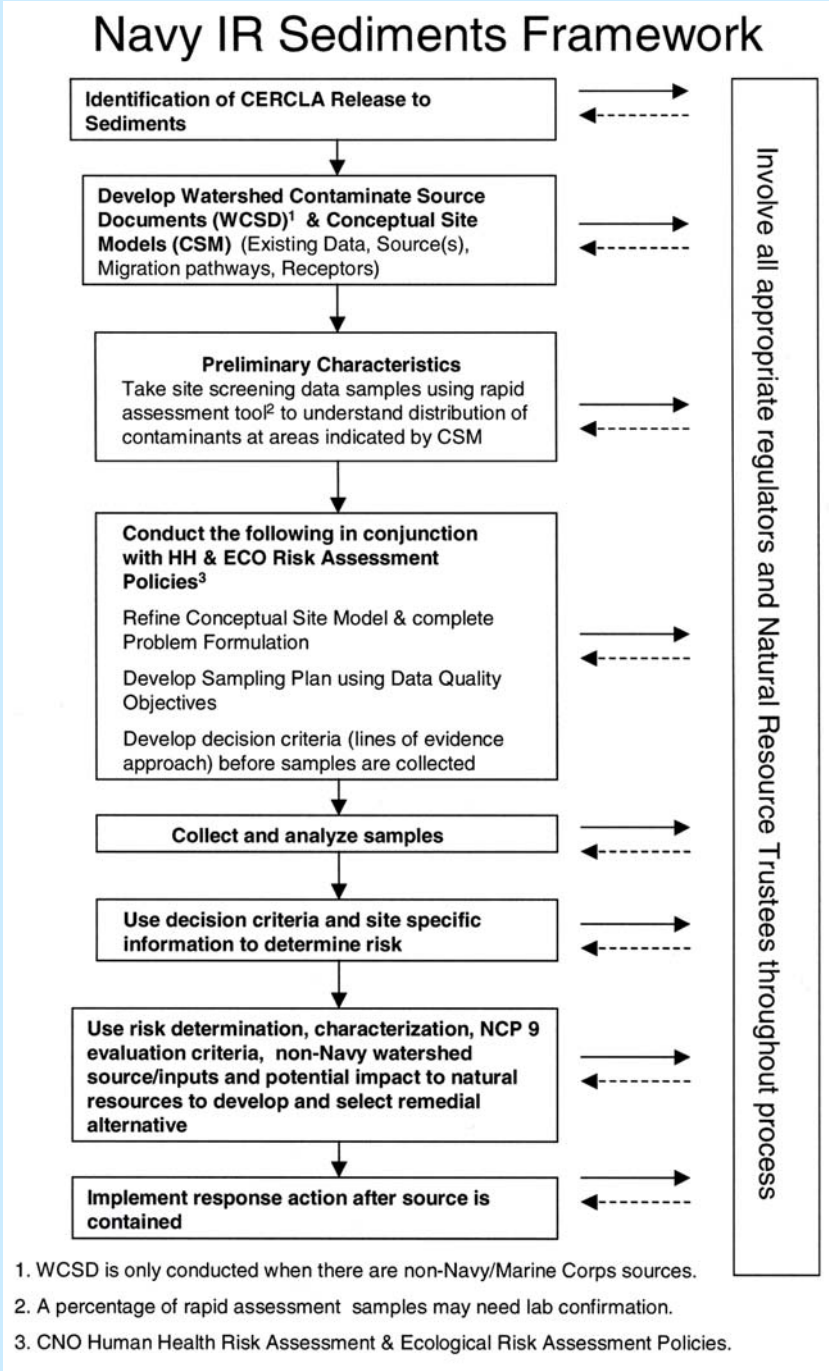
Purpose of Policy

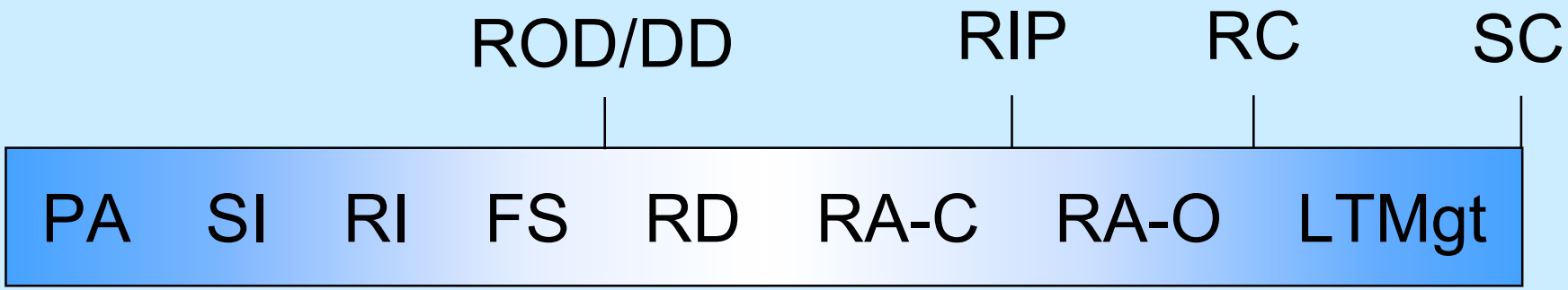
- The CNO Sediment Policy was developed to address concerns in the IR/BRAC Program, such as:
  - When do we sample sediments?
  - Should there be a link to an IR site?
  - Should all drains be sampled?
  - When is cleanup our responsibility?
  - When can ER,N/BRAC funds be used?
  - Can we join other entities to investigate?
  - When should legal get involved?
  - When and where should we document our findings?

Policy Overview

- This policy has six statements pertaining to:
  - Source identification and Navy's responsibility
  - Link to Navy CERCLA/RCRA site
  - Consistency with other Navy policies
  - Risk-based, site-specific investigation and cleanup goals
  - Source containment prior to cleanup
  - Monitoring considerations
- Includes the Navy IR Sediment Framework



The IR Process



PA – preliminary assessment
SI – site investigation
RI – remedial investigation
FS – feasibility study
ROD/DD – record of decision/decision document
RD – remedial design
RA-C – remedial action construction
RIP – remedy in place
RA-O – remedial action operation
RC – response complete
LTMgt – long-term management
SC – site closeout

CNO Sediment Policy Statement #1

All sources shall be identified to determine if the Navy is solely responsible for the contamination.

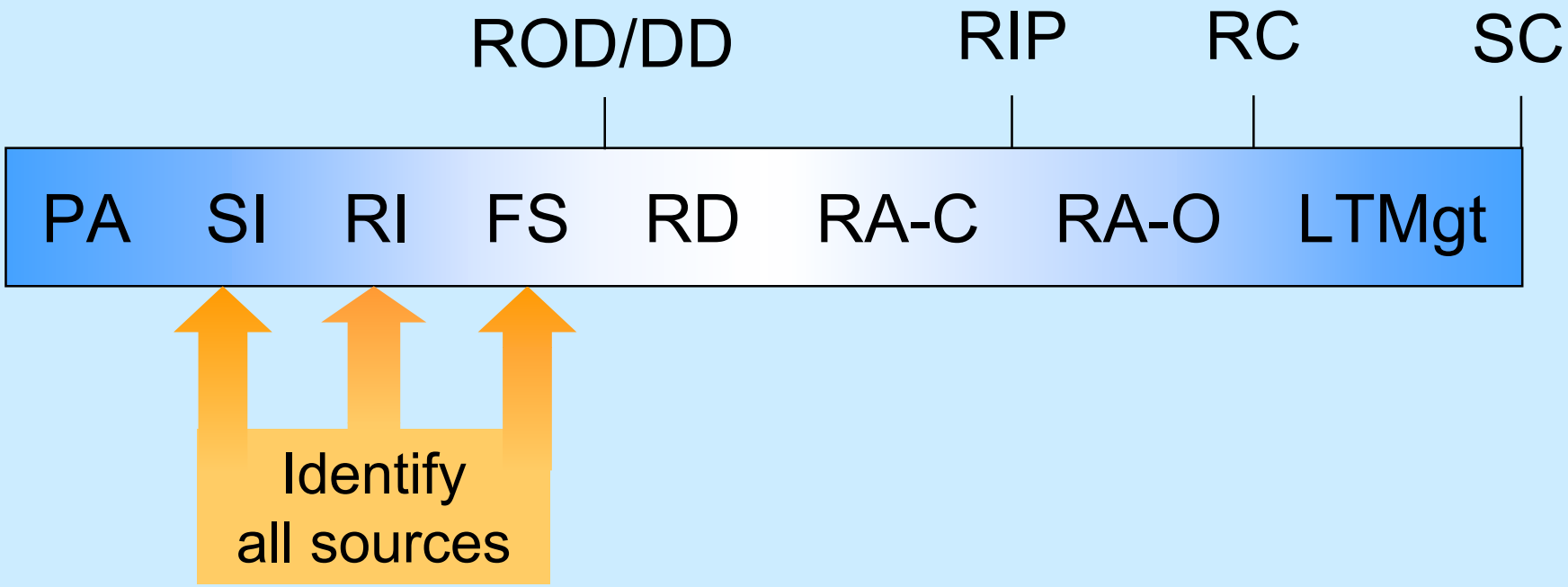
- Identify all sources (Navy and non-Navy)
- Develop WCSD if other sources are present
- If primary source is non-Navy, cease funding and consult counsel for direction

CNO Sediment Policy Statement #1
Components of a WCSD

- Watershed Contaminant Sources Document (WCSD)
  - Summary document 2 to 10 pages
  - Lists all sources
  - Identifies potential contaminated sources, releases, transport routes, etc.
  - Documents the existence of non-Navy sources
  - Conducted only when there are potential other sources
  - Contains a pictorial CSM
  - Given to regulators

CNO Sediment Policy Statement #1

IR Process



CNO Sediment Policy Statement #1

Source Identification Example

- Many Navy facilities are located in industrial and commercial waterways
- Sources must be identified

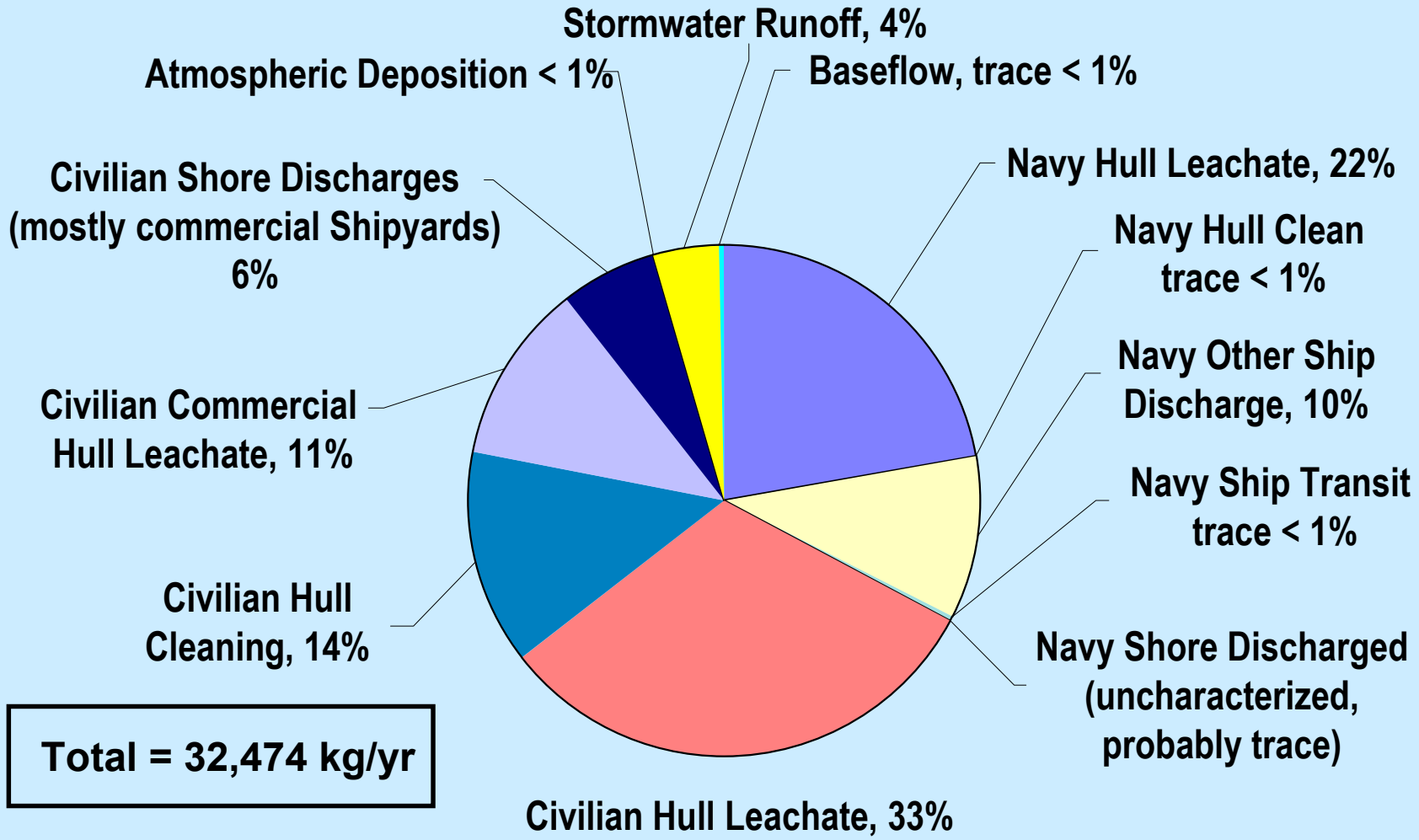
Potential Key Sources Central San Diego Bay

Source: SSC San Diego

CNO Sediment Policy Statement #1

Source Identification Example

Estimated San Diego Bay Annual Dissolved Copper Load



Source: SSC San Diego

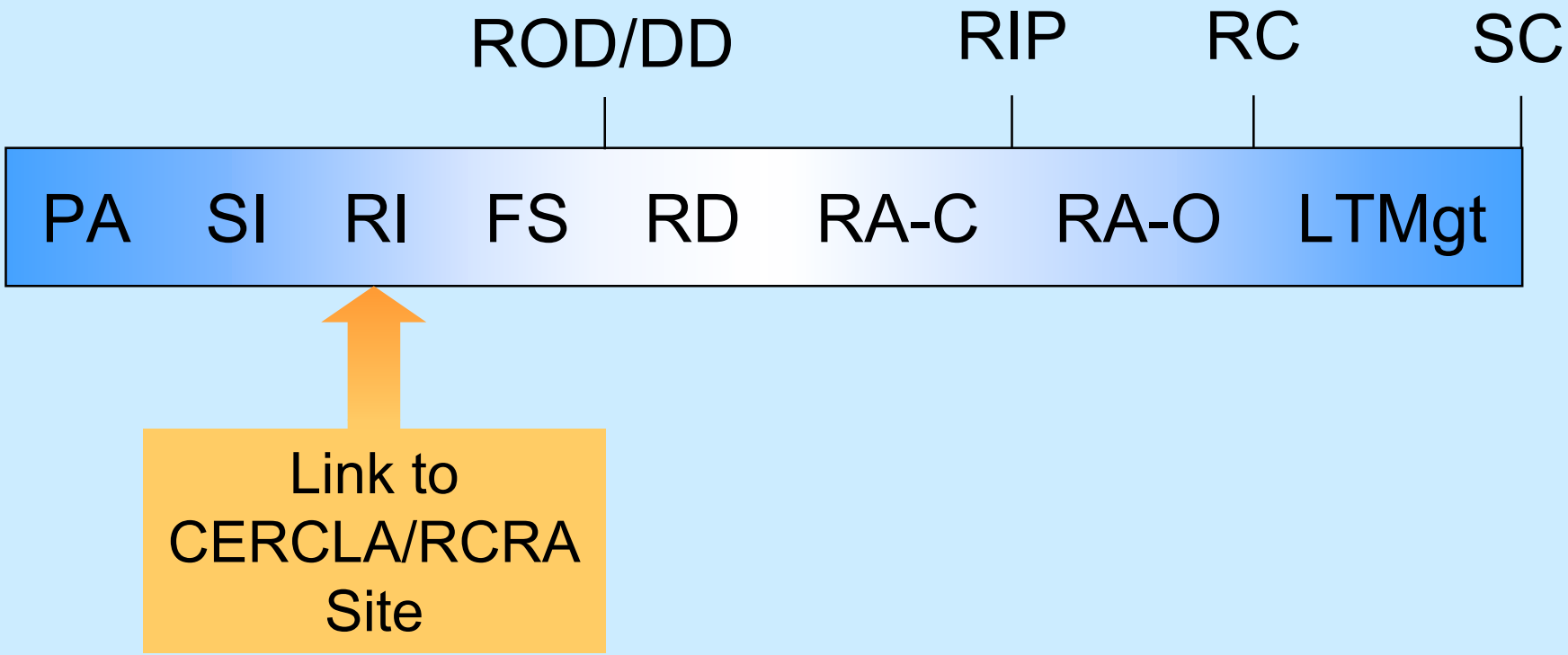
CNO Sediment Policy Statement #2

All investigations shall primarily be linked to a specific Navy CERCLA/RCRA site.

- Contamination must be linked to CERCLA/RCRA site
- Use planning tools to characterize the site
- Use innovative investigative tools
- When sources are Navy-only, using a watershed approach can be appropriate
- However, need approval from CNO N45 to conduct watershed investigation with non-Navy entities

CNO Sediment Policy Statement #2

IR Process

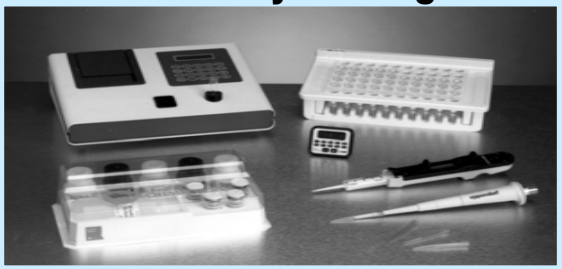


Policy Statement 2 Example

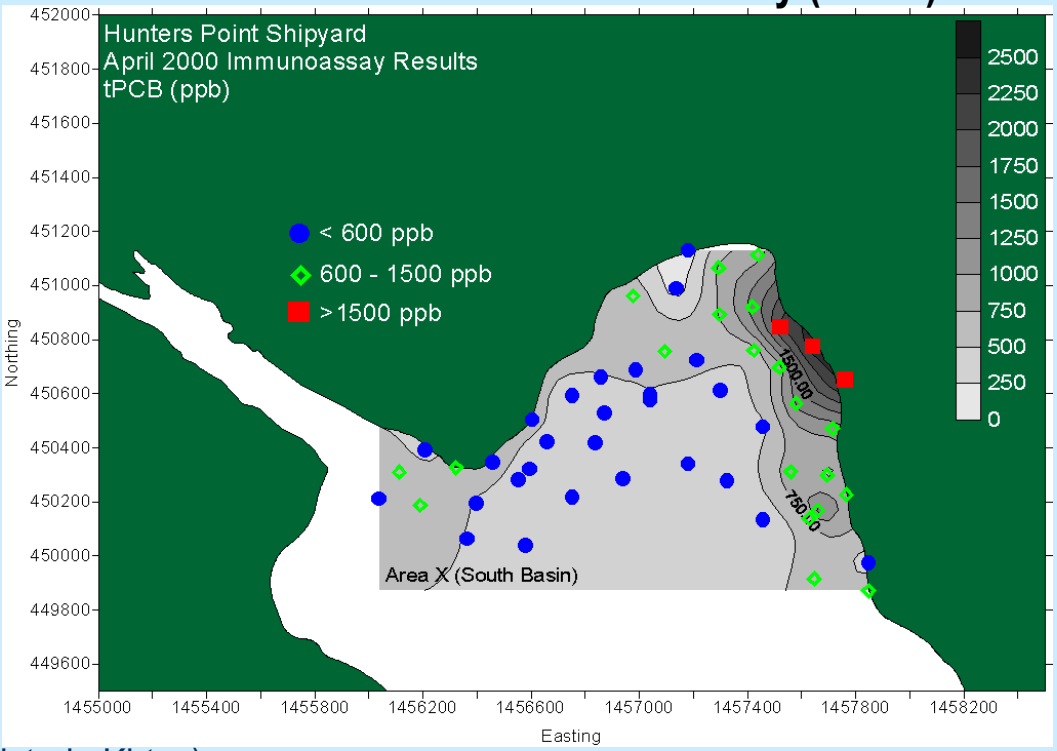
- PCB results compared to site-specific benchmarks may divide area into strata targets for standard regulatory test
- Subsequent high-quality PCB congener analysis indicated that there were two sources (Navy and non-Navy)
- In this case, per policy, CNO approval is required for watershed approaches

Field Screening for Sediments

Immunoassay for Organics



Hunters Point Sediment Study (PCBs)



Source: SSC San Diego (POC Dr. Jim Leather/Victoria Kirtay)

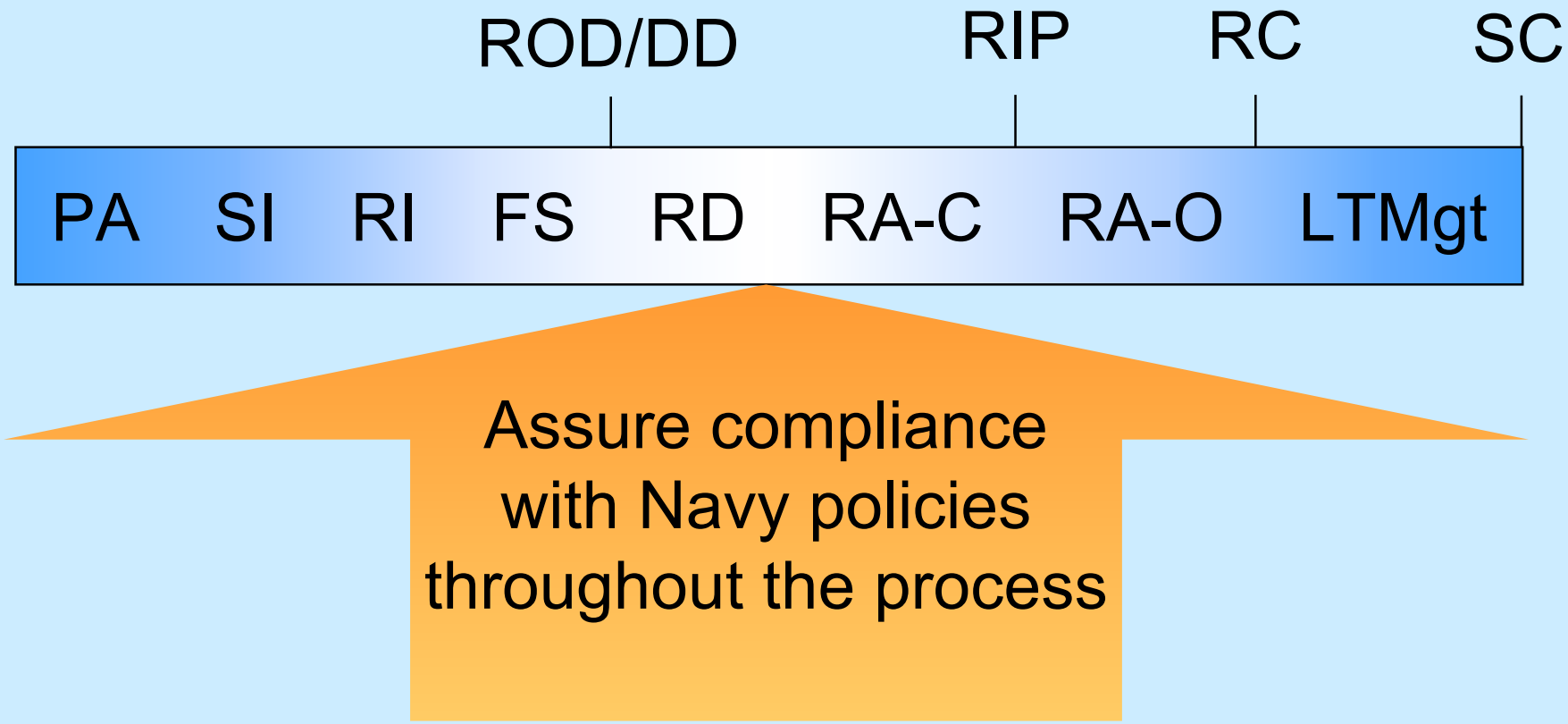
CNO Sediment Policy Statement #3

All sediment investigations and response actions shall be consistent with Navy polices on risk assessment and background chemical levels.

- Consult NAVFAC website for Navy guidance at: http://web.ead.anl.gov/ecorisk/policy/
  - Risk Assessment, 4/99
  - Background Chemical Levels, 9/00
  - Human Health Risk Assessment, 2/01
  - Potentially others…

CNO Sediment Policy Statement #3

IR Process



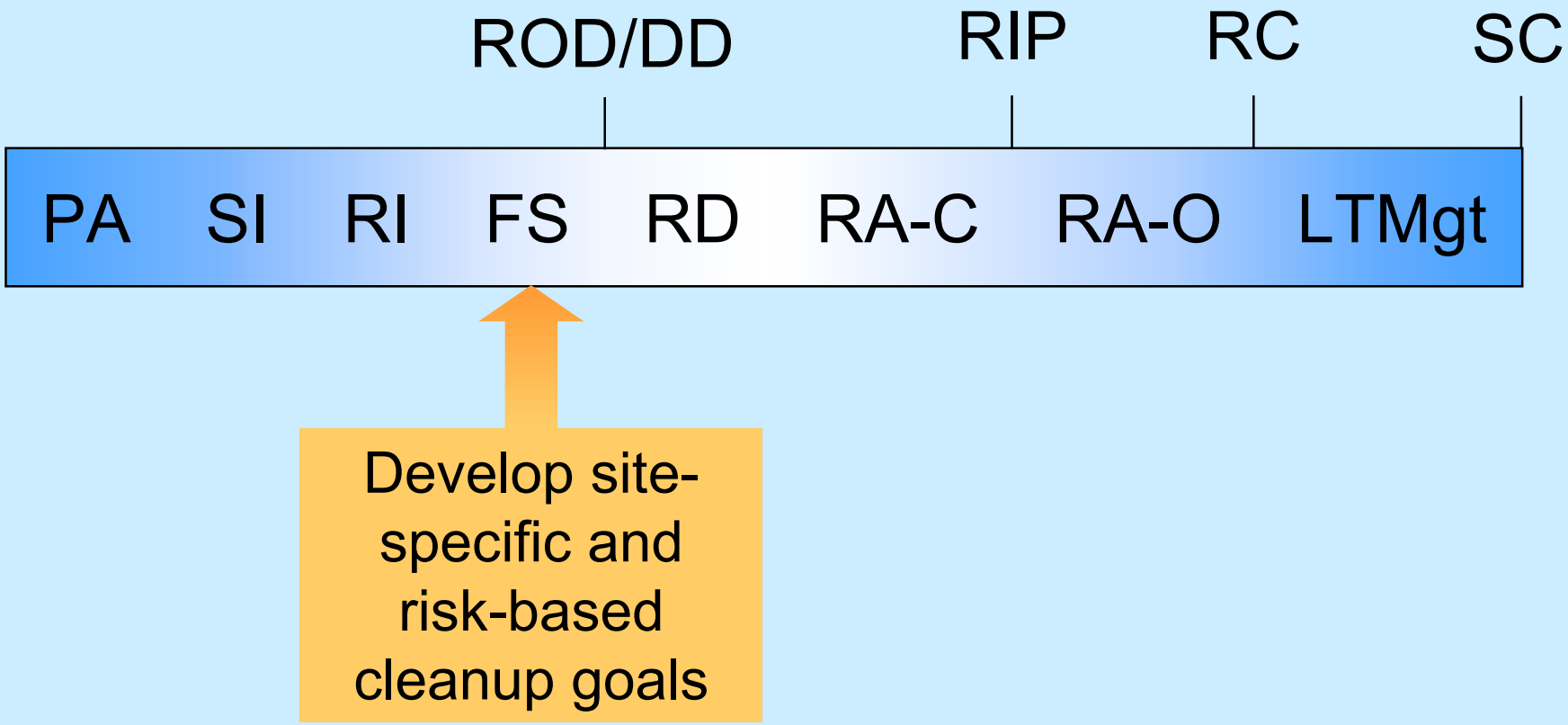
CNO Sediment Policy Statement #4

Sediment cleanup goals shall be developed based on site-specific information and shall be risk-based.

- Unacceptable risks must be directly attributed to a Navy CERCLA source
- Cleanup goals must be achievable
- Ecological screening values must not be used as cleanup goals
- All reasonable response alternatives must be evaluated

CNO Sediment Policy Statement #4

IR Process

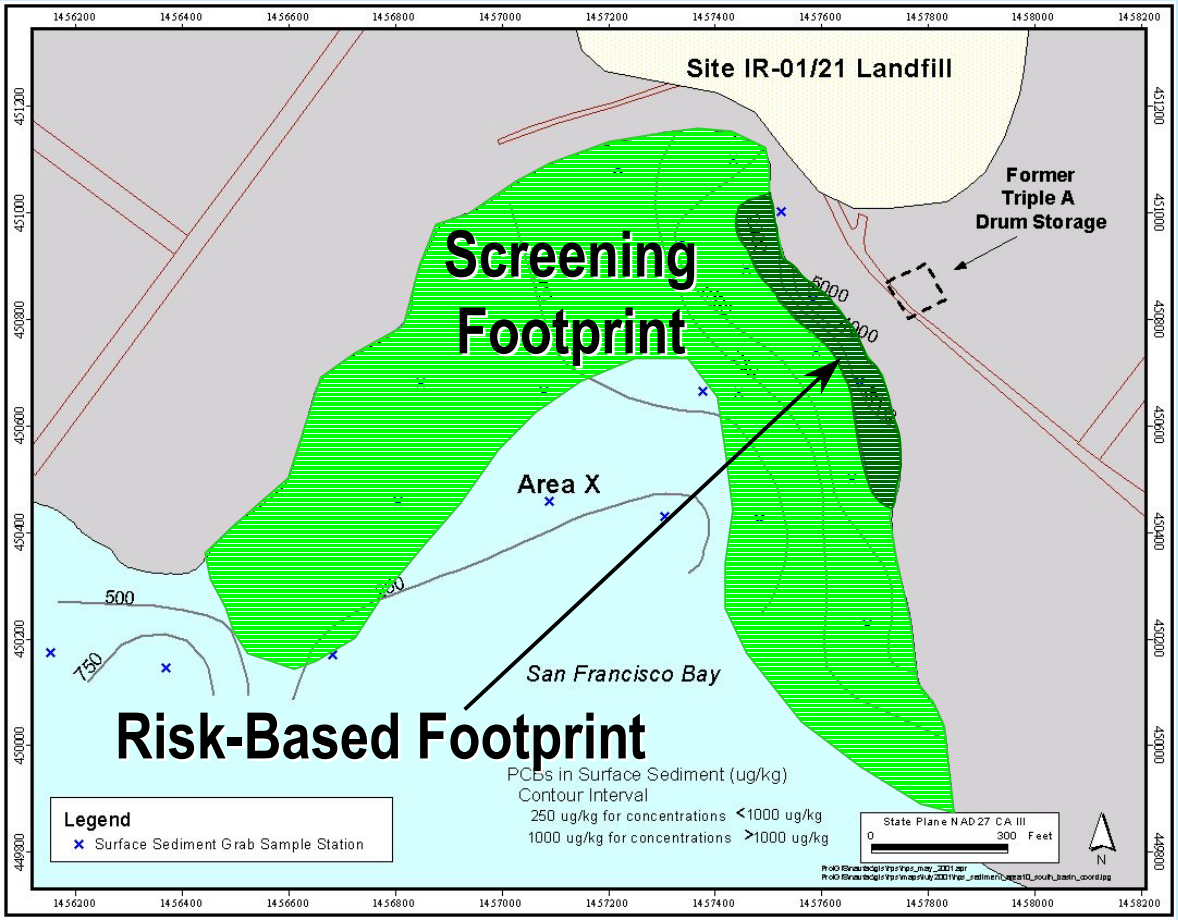


CNO Sediment Policy Statement #4

Risk-Based Cleanup Example

Hunters Point Shipyard

- Initial footprint was based on screening values (e.g. ER-Ms and literature) at 120,000 CY (not all shown on this slide)
- Proposed footprint based on site-specific WOE approach. Boundary at 2 ppm total PCBs contour with volume of 3,000 CY



Source: SSC San Diego

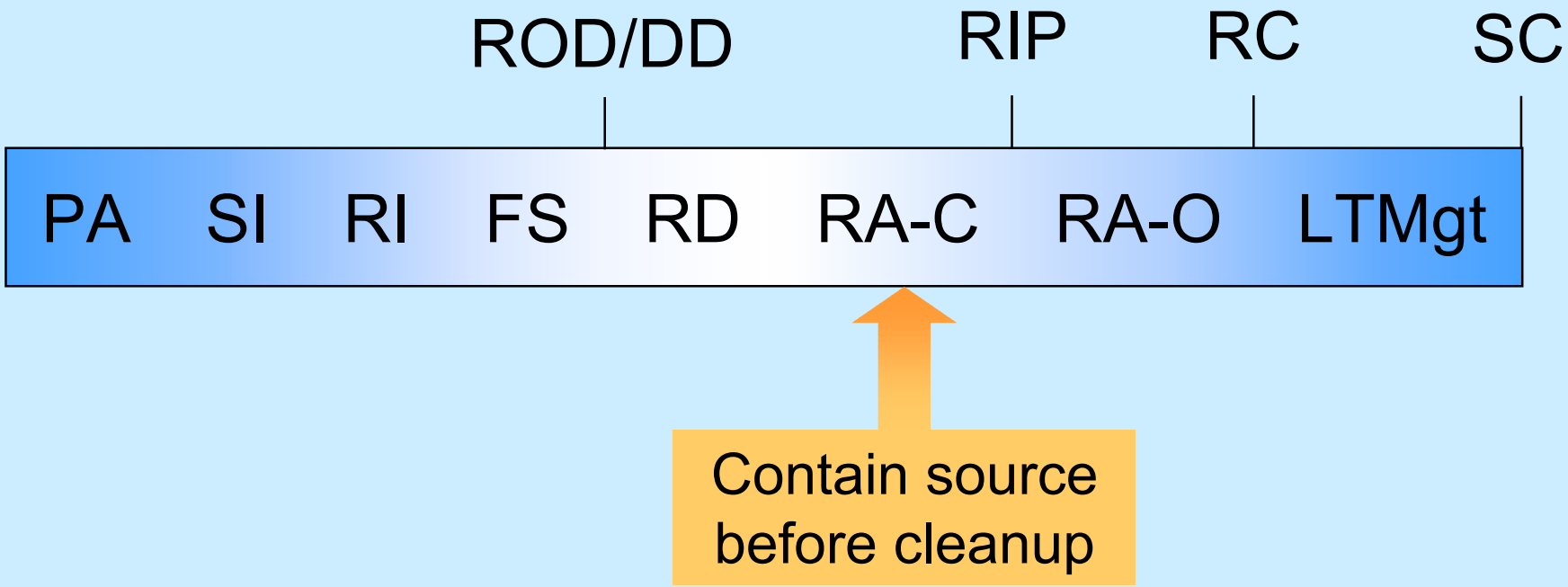
CNO Sediment Policy Statement #5

The Navy shall not clean up contamination from a non-Navy source where the Navy has not contributed to the risk in sediments. The Navy will not clean up a site before the source is contained. Any potential re-contamination by non-Navy sources shall be documented.

- Navy sources that demonstrate unacceptable risk will be remediated
- If potential for recontamination for other non-Navy sources
  - Document in investigation report, Record of Decision (ROD), and response action (RA) closeout report

CNO Sediment Policy Statement #5

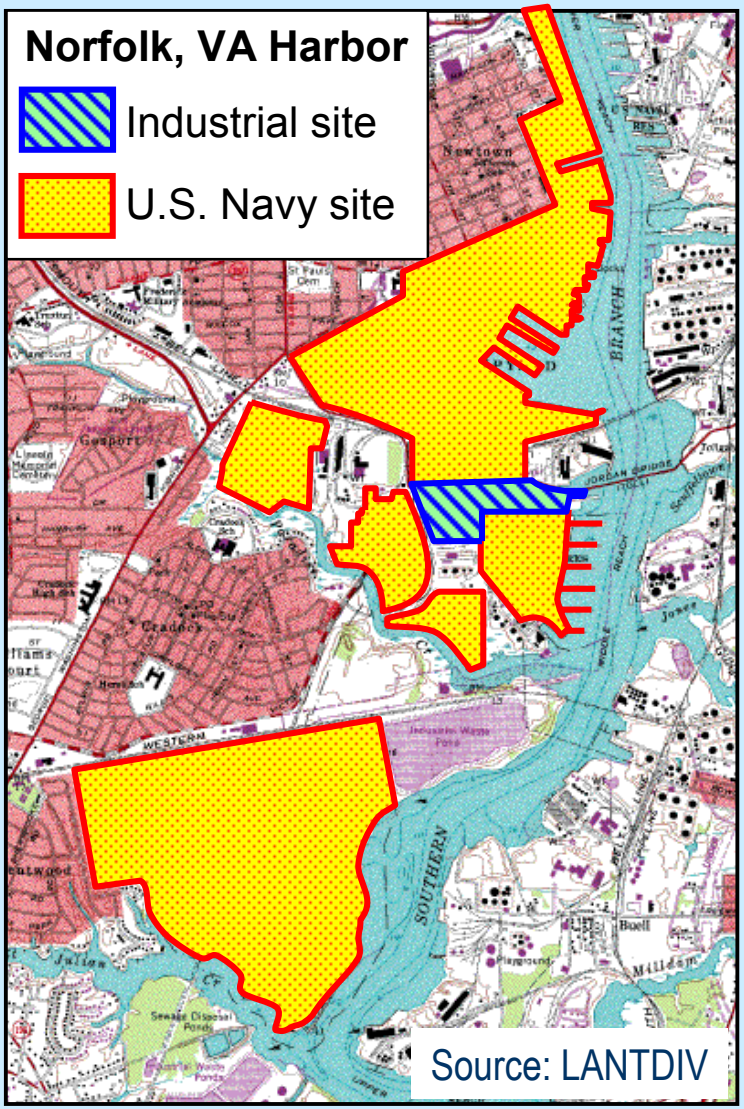
IR Process



CNO Sediment Policy Statement #5

Source Containment Example

- Company adjacent to Navy property and can potentially re-contaminate area with PAHs
- Navy site also has potential PAH contamination with different chemical signature
- Navy properly delineates contaminated areas
- Navy could potentially be asked to remediate PAH levels
- Document in investigation report, ROD, and RA closeout report



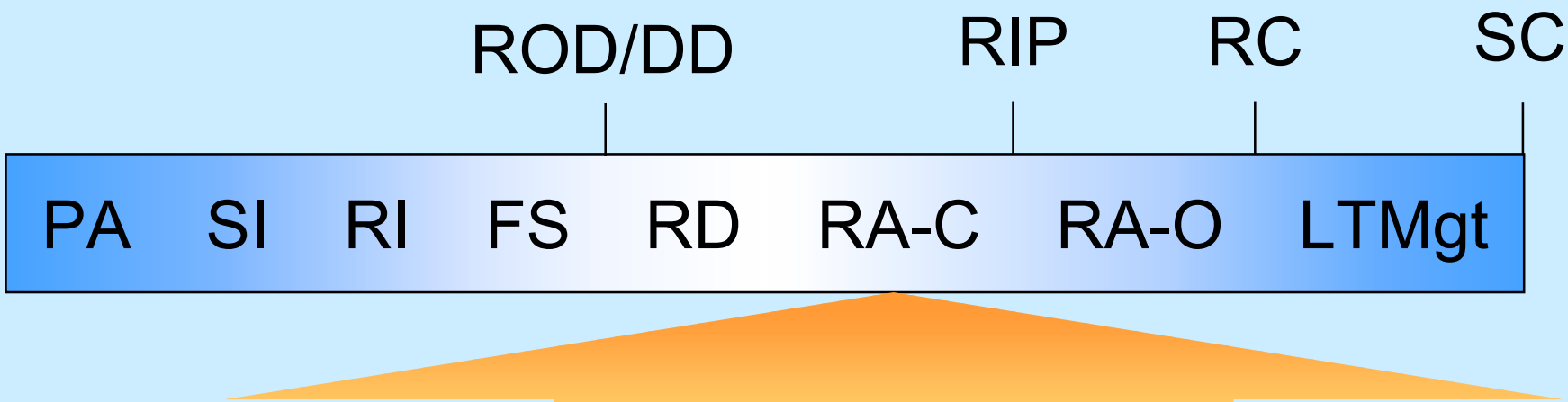
CNO Sediment Policy Statement #6

A monitoring plan with exit strategies shall be developed before collecting the first monitoring sample.

- Clearly establish monitoring objectives using data quality objectives (DQOs)
  - Verify source containment or removal
  - Demonstrate habitat restoration
  - Confirm remedy integrity and stability
- Develop Sampling and Analysis Plan (SAP)
  - Sample type and method (chemical, biological, toxicity)
  - Sample number and locations
  - Sampling frequency, duration, and 5-year review periods
- Define exit strategies
  - Exit strategies coincide with monitoring objectives i.e., DQOs
  - Eliminate data requirements not related to decision making

CNO Sediment Policy Statement #6

IR Process

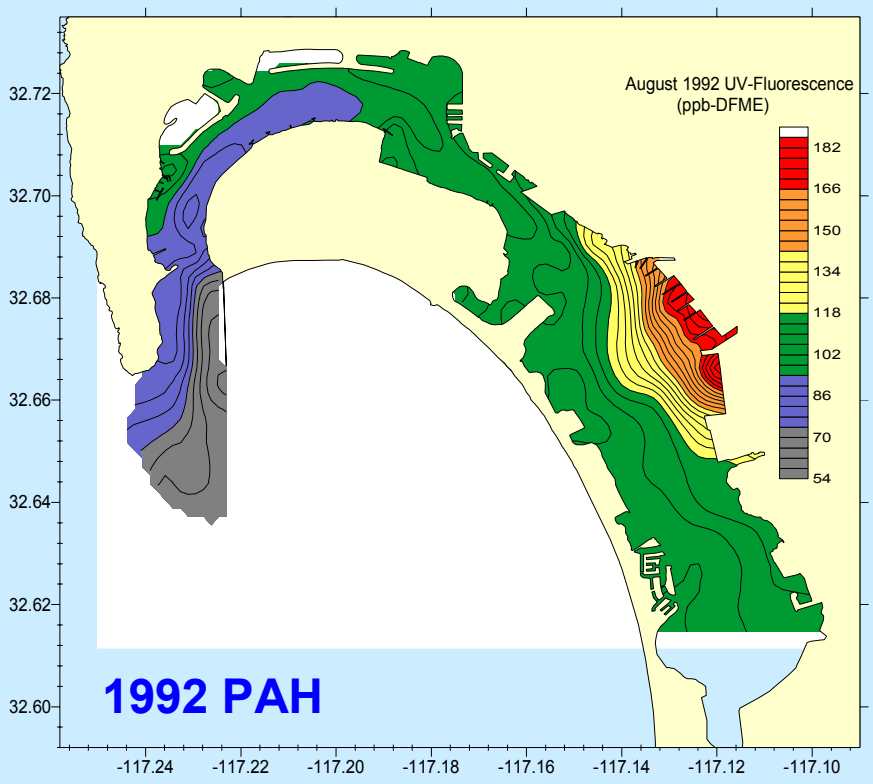


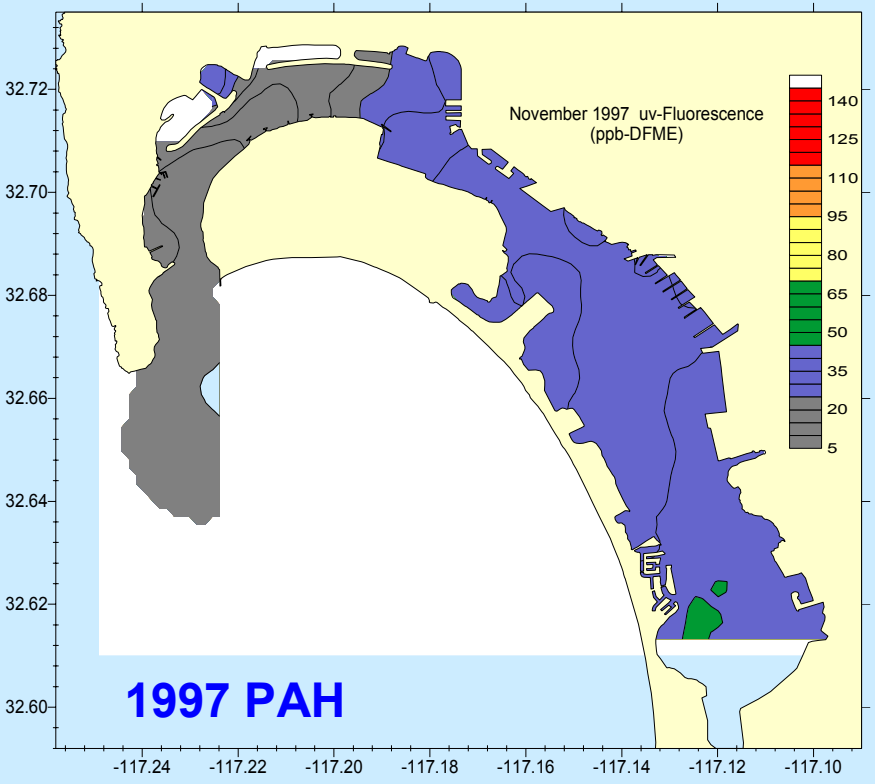
Monitoring considerations are addressed in various phases in the process and documented in the ROD

CNO Sediment Policy Statement #6

Monitoring Example

- Long-term monitoring data allowed NAVSTA San Diego to document significant PAH reductions due to pollution control operations



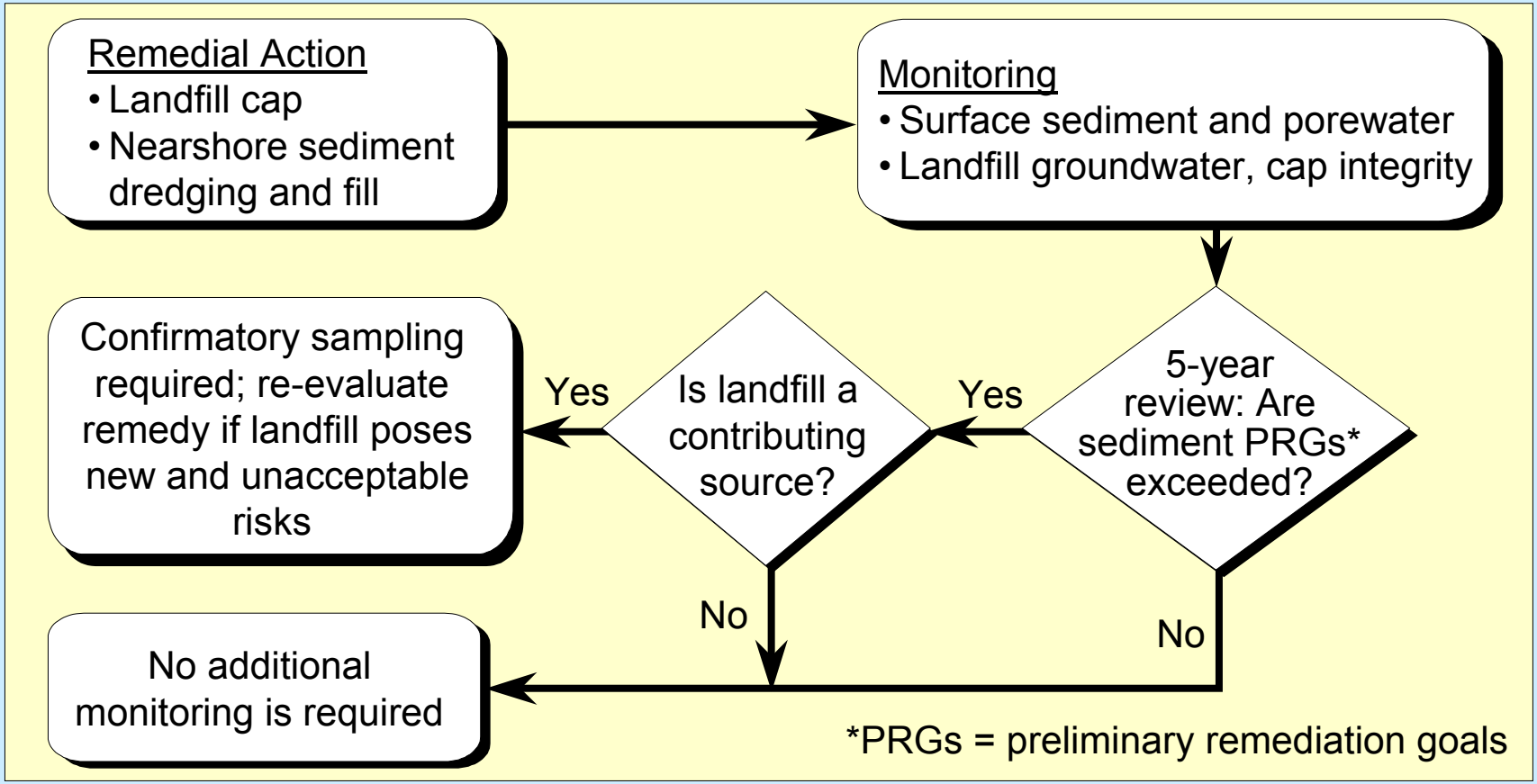


Source: SSC San Diego

CNO Sediment Policy Statement #6

Monitoring Example

- Monitor nearshore sediments adjacent to a capped landfill, after treatment
  - Dredged and refilled nearshore sediments
  - Monitor sediments for rebound
  - Monitor potential landfill (groundwater and visual inspection) releases



CNO Sediment Policy Conclusions

- To be considered when conducting sediment investigations:
  - Source(s) identification and Navy responsibility
  - CSM refined during process
  - Established links to known Navy sources
  - Remediation that is site-specific and risk-based
  - Source containment before cleanup
  - Integrated, site-specific monitoring plan and exit strategies

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Goal, Purpose and Scope

- Goal:
  - To develop a guidance document to address issues associated with sediment investigations and remediation in accordance with CNO Policy
- Purpose:
  - To address procedures for identification, investigation, management, and sediment site closure within Navy's IR Program
  - To provide practical, technically sound extension of existing Navy and regulatory policy/guidance to RPMs and technical support
- Scope:
  - Specific to sediments (primarily CERCLA-related studies)
  - Comprehensive in breadth, yet concise with Web links and references to further resources
  - Relies on current state-of-the-science, acknowledging evolving methodologies and technologies

Participation and General Information

- Guide was prepared as a product of the NAVFAC Risk Assessment Workgroup (RAW) Sediment Subgroup
  - Team Lead: Jason Speicher (EFANE)
  - Members
    - Kim Parker Brown (NAVFAC HQ), Chris Leadon (SWDIV), Ed Corl (LANTDIV), Bill Hill (SOUTHDIV), Ruth Owens (NFESC), Stacey Curtis (SSC)
- Draft reviewed by full RAW and two contractors
- Currently finalizing Final Draft for broad Navy and outside review

NAVFAC Sediment Guide Content

- Introduction
  - Document organization, overview of Navy guidance and relevant regulations, laws and guidelines
- Sediment Site Characterization
  - Aquatic vs. terrestrial studies
  - Physical, chemical, and biological characterization
  - Source identification/forensics
  - Contaminant fate and transport
  - Overview of field sample collection methods

NAVFAC Sediment Guide Content (cont.)

- Risk Assessment
  - Ecological Risk Assessment (ERA)
  - Human Health Risk Assessment (HHRA)
  - Sediment-specific issues in screening and baseline risk assessment tiers/steps
- Sediment Remedial Alternative Evaluations
  - Planning considerations, remediation goals, cleanup levels, remedial option selection, monitoring considerations

Summary

- Addresses complexity of sediments that require further guidance
- Meets the lack of practical specific guidance for assessing and managing sediments
- Provides concise coverage of sediment issues with links to more detailed resources
- Is being developed in the midst of evolving regulatory and scientific efforts addressing assessment and management of contaminated sediments

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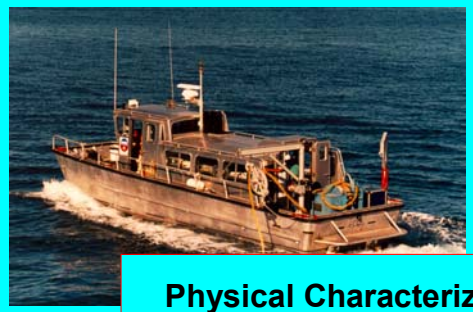
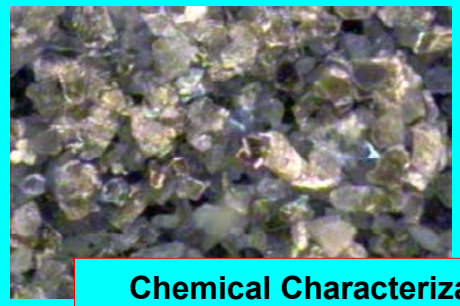
Sediment Site Characterization

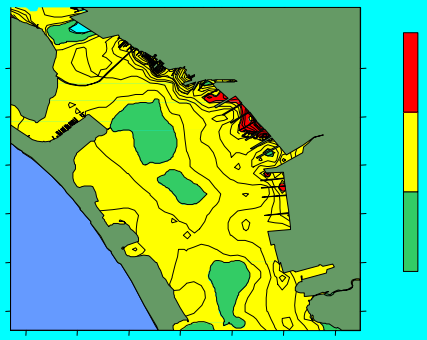
Field Surveys



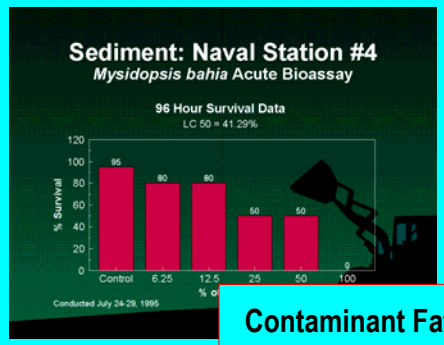
Physical Characterization



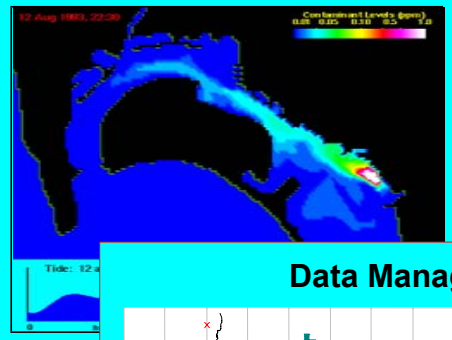
Chemical Characterization



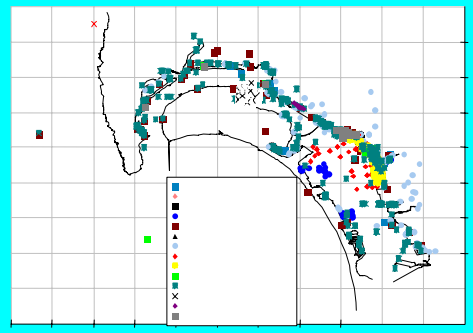
Biological Characterization



Contaminant Fate and Transport



Data Management



Source: SSC San Diego

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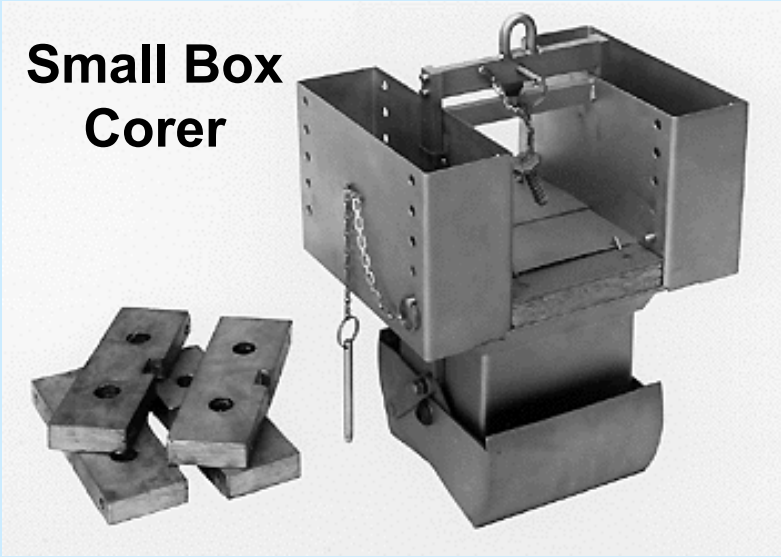
Collection of Aquatic Samples

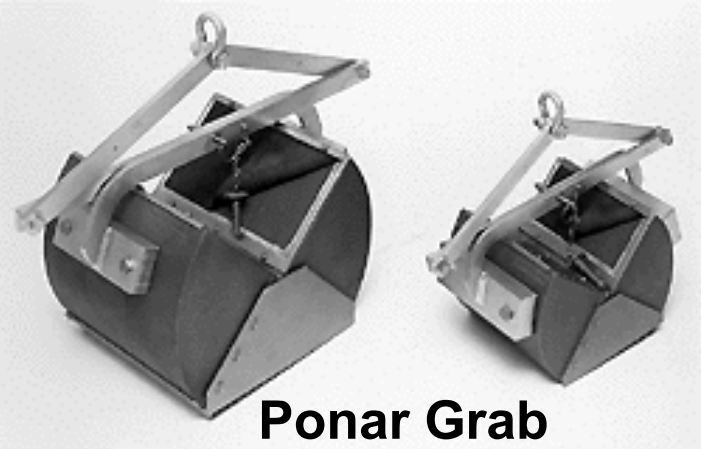
- Generally is divided into six tasks
  - Mobilization
  - Navigation
  - Sediment sampling
  - Sample processing
  - Demobilization
  - Field quality control
    - Monitored according to project needs
    - Field and rinsate blanks,
    - Field splits or replicates

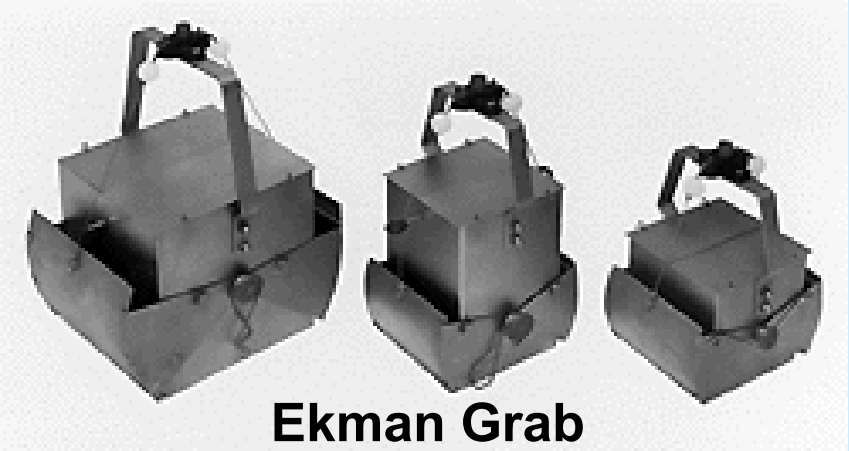
Pictures: SSC San Diego

Collection of Surface Sediment Samples

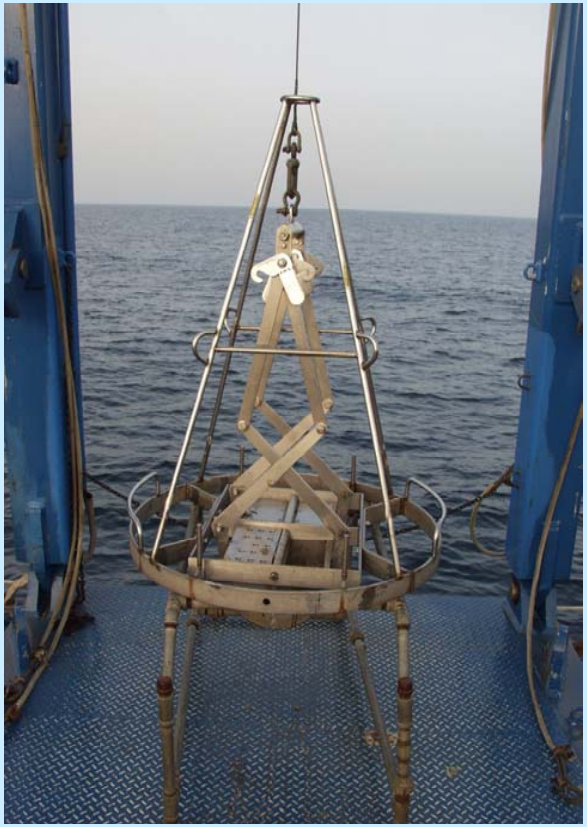
- Usually are collected with a grab sampler such as:
  - a box-corer
  - an Ekman grab
  - a Ponar grab
  - or a Van Veen grab







Example of a Dual 0.1 m^2 Van Veen Grab



Grab before deployment

Two sediment samples

Rapid Sediment Characterization (RSC) Tools

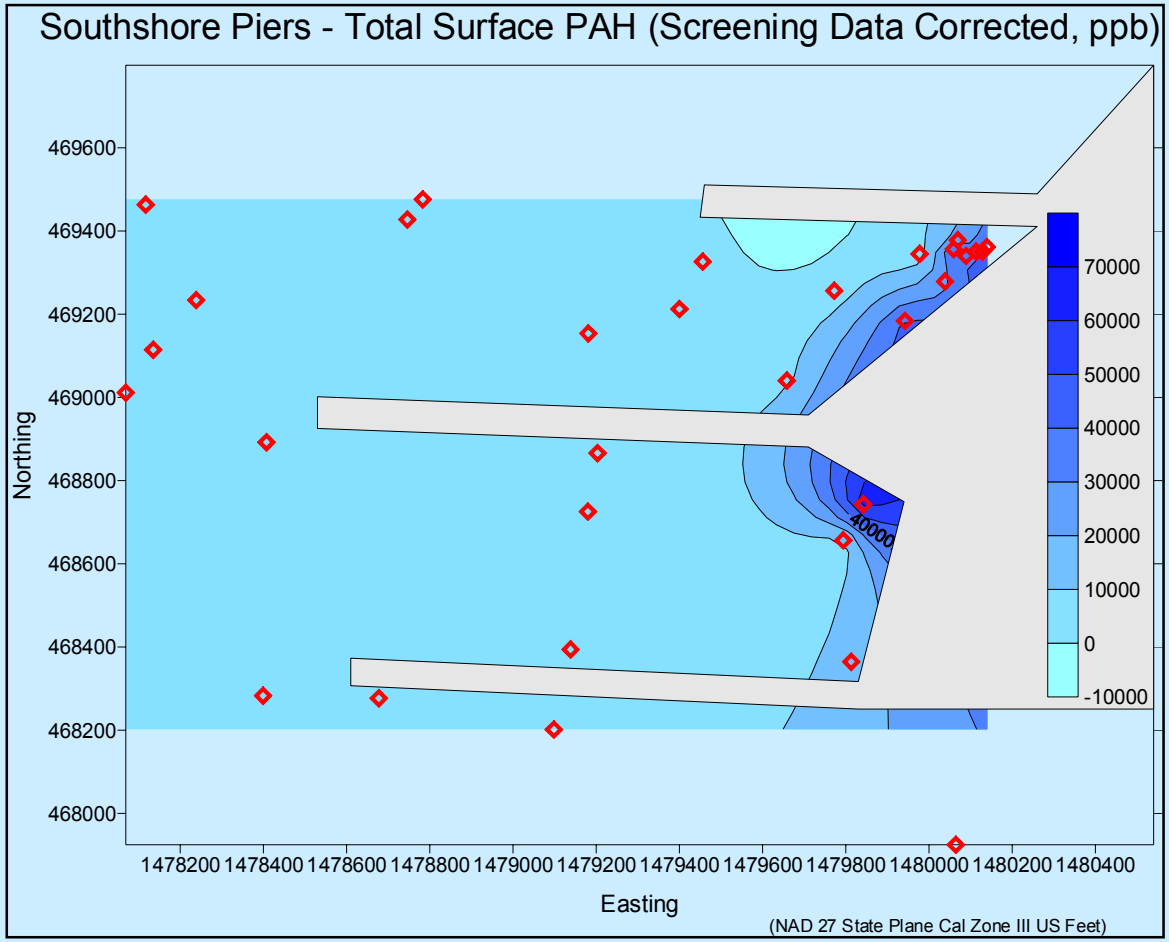
- RSC tools are field transportable analytical tools that provide measurements of chemical, biological, or physical parameters on a real-time or near-real time basis; often are commercial off-the-shelf (COTS) units
- Tools can be used individually or in concert depending on data needs
- Examples of tools
  - Chemical measurements
    - X-ray fluorescence (XRF) for metals
    - Immunoassay for organics (PCBs, PAHs and pesticides)
    - All methods are modified U.S. EPA SW-846-approved methods
  - Biological measurements
    - QwikSed bioassay for biological effects
  - Physical measurements
    - Particle size, moisture, density

RSC Tools

- RSC tools are encouraged in the policy and guidance to:
  - Optimize field sampling designs
  - Increase the probability of successful, high-impact sampling
  - Cost effectively use high-quality laboratory analytics in combination
  - Provide the ability to fill in gaps and reduce uncertainty at several steps of the RI/FS process without the high cost of traditional re-sampling efforts
  - Map contaminated sediment volumes more efficiently to reduce remediation costs

Example: RSC Tools Used for Pier Area PAHs

- A few PAH hits at site drove discussions
- One day of higher density rapid screening analysis suggested that PAHs in sediments were associated with creosote pier pilings
- Selected samples underwent laboratory analysis which confirmed creosote impact

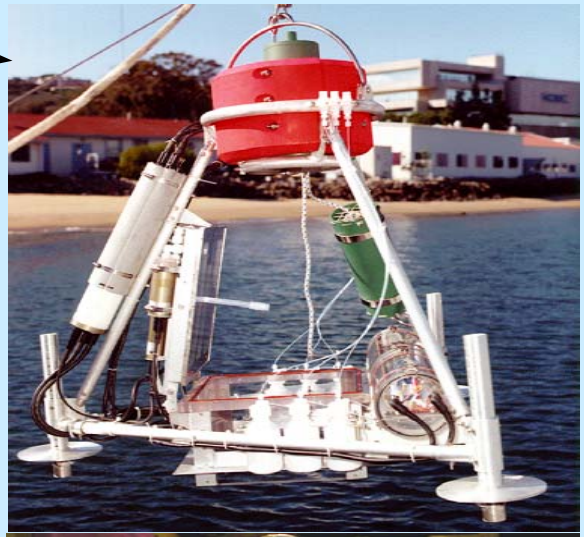


Source: SSC San Diego (POC Dr. Jim Leather)

Example: Benthic Assessment Tools

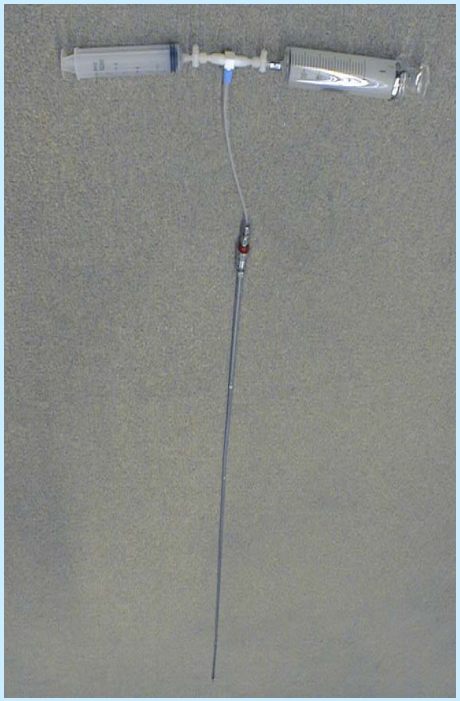
Are the contaminants mobile?

- **Benthic Flux Sampling Device**
  - Measure diffusional fluxes of contaminants between sediment and overlying water



- **Multi-Sample Seepage Meter**
  - Measure groundwater/ contaminant seepage in regions of tidal influence

- **Diver-Deployed Porewater Probe**
  - Measure interfacial water concentrations at a specified depth within the sediment



Source: SSC San Diego
(POC Dr. Bart Chadwick)

Example: Benthic Assessment Tools

Source: SSC San Diego

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Physical Characterization

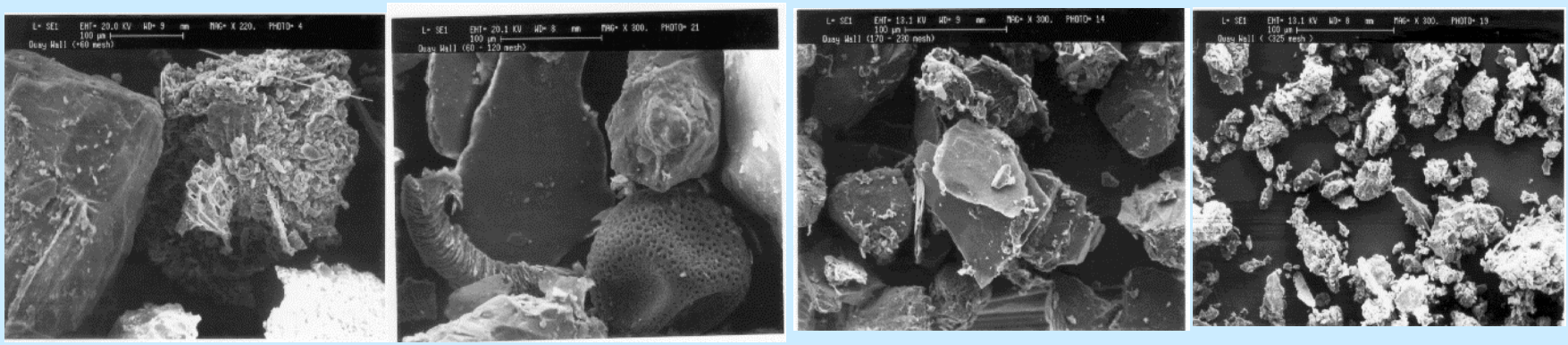
- Physical characteristics and other supplemental data must be considered in sediment site investigations because they can:
  - Influence contaminant loading
  - Affect bioavailability
  - Introduce factors that confound test results
  - Influence sediment management / remedial alternative selection
- Additionally, geotechnical data are needed to evaluate engineering properties of sediment for remedial design
  - Typically consist of sediment strength, cohesion, compressibility, porosity, and dewatering characteristics

Physical and Supplemental Data

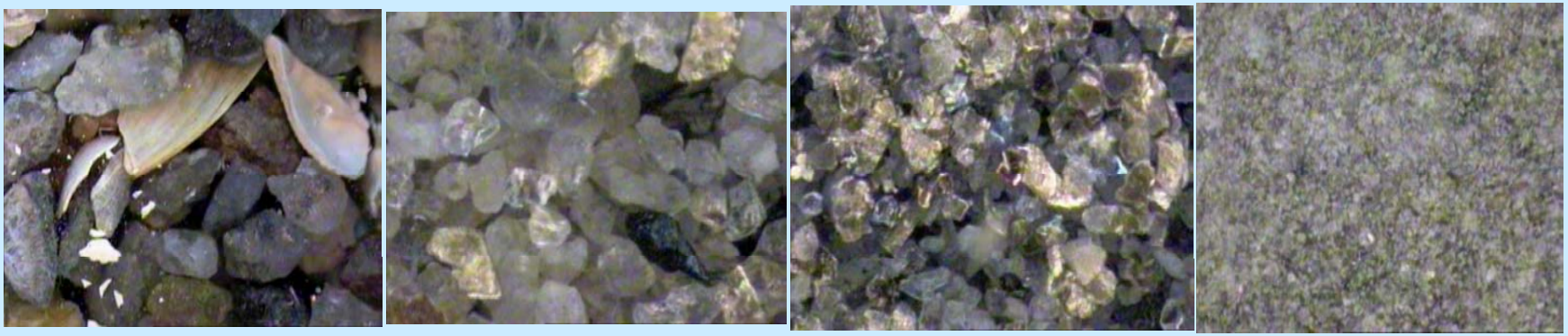
Parameter	Importance
Total Organic Carbon (TOC)	TOC tends to sorb contaminants, therefore contaminant concentrations tend to increase with increasing TOC; however, contaminants may be less bioavailable in sediments with high TOC (e.g., >2%)
Sediment Grain Size (GS)	Finer-grained sediments tend to sorb contaminants; GS can be used to estimate hydrodynamics; GS affects benthic community structure
Ammonia & Sulfide	They are naturally occurring toxicants in organically-enriched sediments
Acid Volatile Sulfide (AVS)	Aids in the interpretation of metal bioavailability
Salinity	Can cause matrix interferences in some chemical analyses; affects benthic community structure; important in selection of bioassay test species
Geotechnical data	Used to evaluate engineering properties for remedial design

Example: Sediment Grain Size

Grain Size and Texture



Sediment Grain Type, Mineralogy, and Source



Source: SSC San Diego (POC Dr. Sabine Apitz)

Management Approach Example: Particle Separation for Volume Minimization

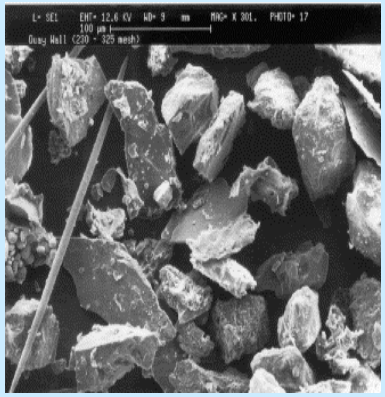
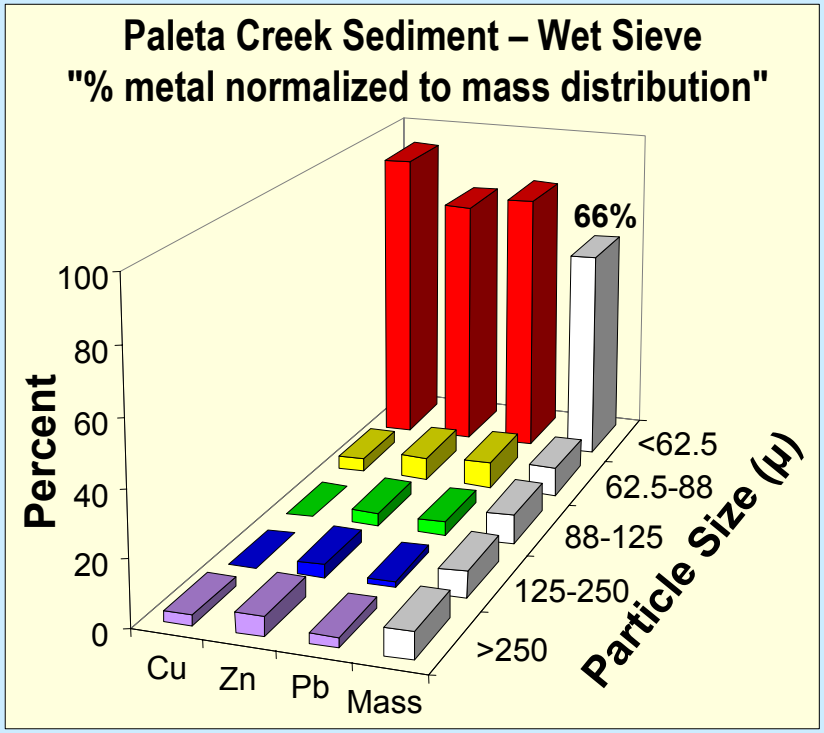
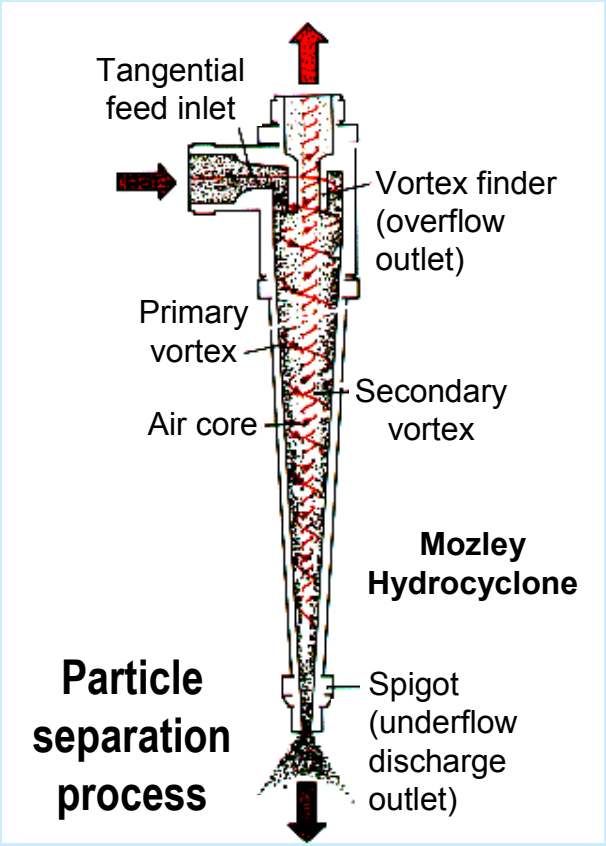


Photo of sediment grains



Metal distribution as a function of grain size



Particle separation process

Source: SSC San Diego (POC Dr. Sabine Apitz)

Physical Characterization Insights

- Measure TOC to evaluate potential bioavailability and contaminant distributions in sediment
- Measure sediment grain size to evaluate contaminant distribution and confounding effects on benthic community characteristics and toxicity test results
- Measure AVS to evaluate bioavailability of sediment metals
- Measure ammonia and sulfide in overlying and/or porewater to address potential confounding factors in toxicity test results

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Chemical Characterization

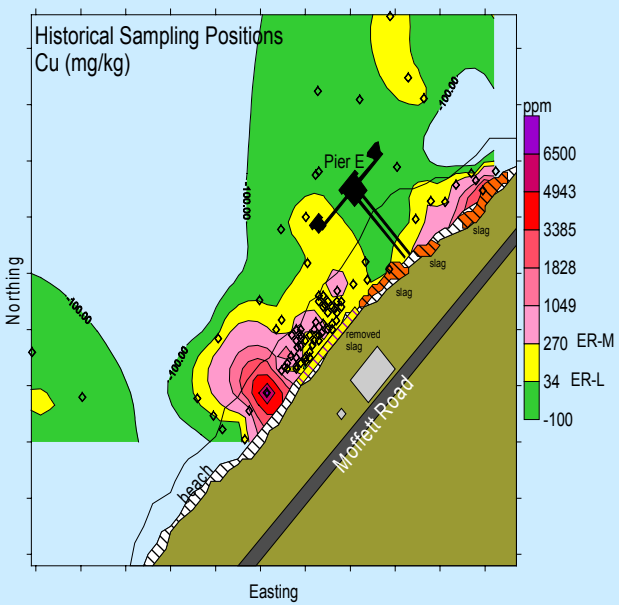
- Analysis of sediment COCs often requires specialized chemistry methods
  - Always use laboratories experienced in analysis of aquatic samples (especially marine)
  - Standard U.S. EPA SW-846 methods usually are not appropriate for analysis of sediment without modification
  - Cost advantages can be achieved through combining RSC and high-quality laboratory analytics
- Typical classes of chemicals found at Navy sediment sites include:
  - Heavy and trace metals, chlorinated pesticides, PAHs, PCBs, and organotins

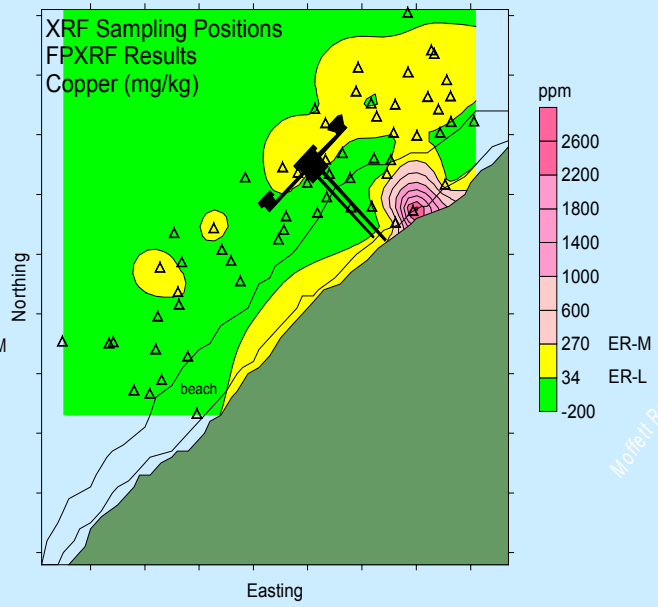
COC Sources

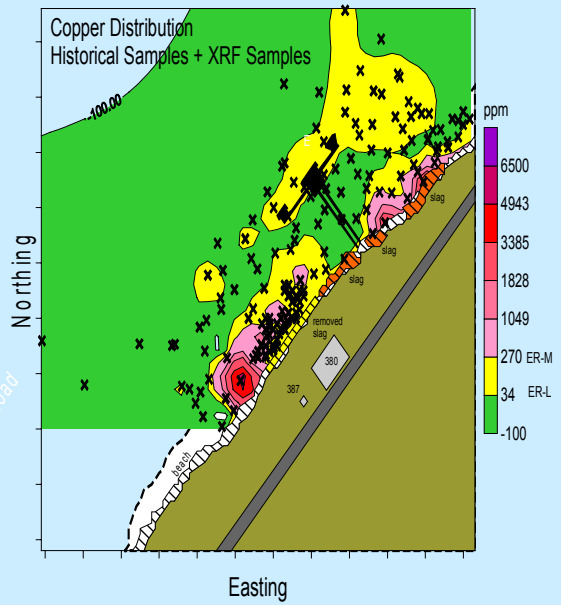
COC Class	Potential Sources
Heavy and Trace Metals	Ship maintenance and building; aerial fallout; sewage effluent; fungicides; old paint (Hg); marine antifoulants (Cu); ballast in submersibles (Hg); former gasoline additives (Pb)
Chlorinated Pesticides	Historical pest control; agricultural runoff
PAHs	Fuel operations and spills; creosote pier pilings; coal tar; asphaltines; fossil-fuel combustion particulates from aerial fallout and road runoff
PCBs	Electrical capacitors and transformers, adhesives, hydraulic oils and paints
Organotins	Marine anti-foulant used in vessel paints

Rapid Sediment Characterization: Metals

NAS North Island Remedial Investigation







Historical Delineation + XRF Delineation = Complete Delineation

- **RPMs and regulators were concerned that impact from copper slag in shoreline sediments might extend beyond sampled**
- **XRF results**
  1) filled in data gaps
  2) confirmed hotspots near Pier E and 3) showed that copper did not extend beyond beach area

Source: SSC San Diego (POCs Dr. Jim Leather/Victoria Kirtay)

Chemical Characterization Insights

- Use published analytical methods appropriate for sediment and aquatic matrices
  - Detection limits suitable for risk assessment
  - Target analytes suitable for source identification
- Use appropriate analytical methods to reduce potential interference from organic matter
  - e.g., Alumina column, gel permeation chromatography, and salt (in marine environments)
- Use techniques such as equilibrium partitioning (e.g., TOC) and geochemical normalization (e.g., Al or Fe ratios) to better understand chemical distributions, potential sources, and chemical bioavailability
- Report sediment results on a dry-weight basis, and tissue generally wet-weight with % moisture and % lipids as ancillary data

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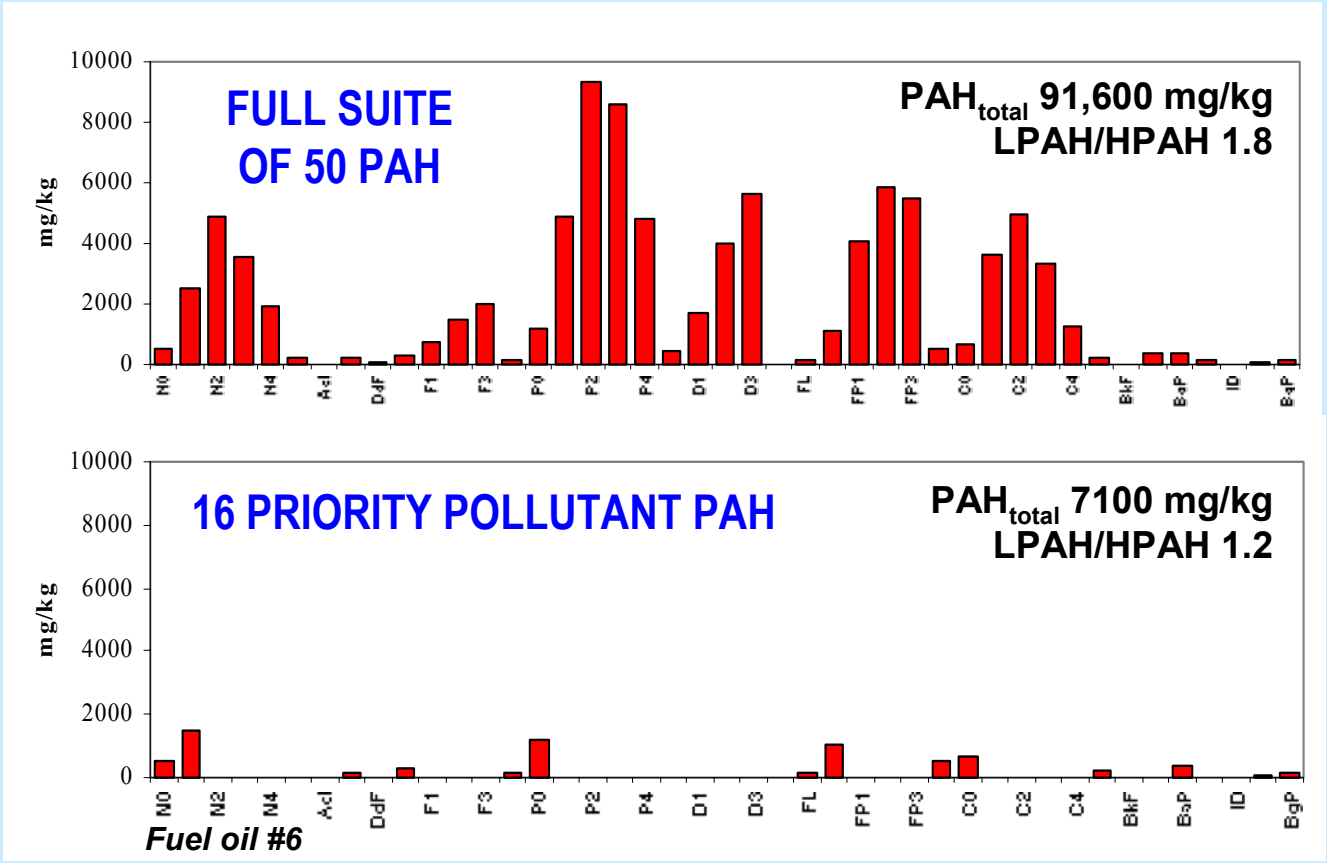
Source Identification/Forensics

- Considered when multiple PRPs are suspected
- Source identification can potentially be very complex
  - Industrial and commercial waterways with multiple sources
  - Broad circulation patterns and physical transport
  - Poorly defined fate and transport pathways
- Typical forensics techniques
  - Used for source identification as well background and weathering information
  - Chemical fingerprinting
  - Geochemical relationships
  - Physical features
  - Modeling
  - Historical records and statistics

PAH Example

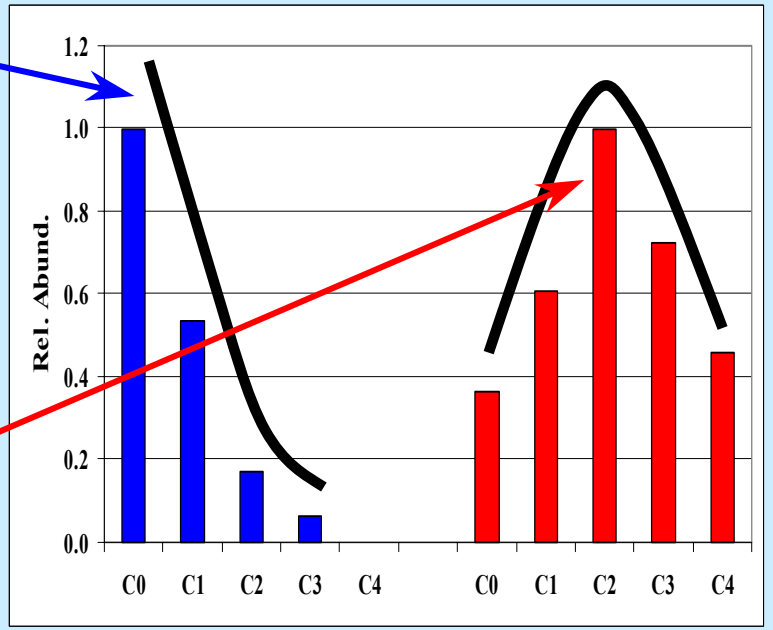
- Quantify the "full PAH suite" to recognize distinct sources



Source: Battelle (POC Scott Stout)

PAH Example

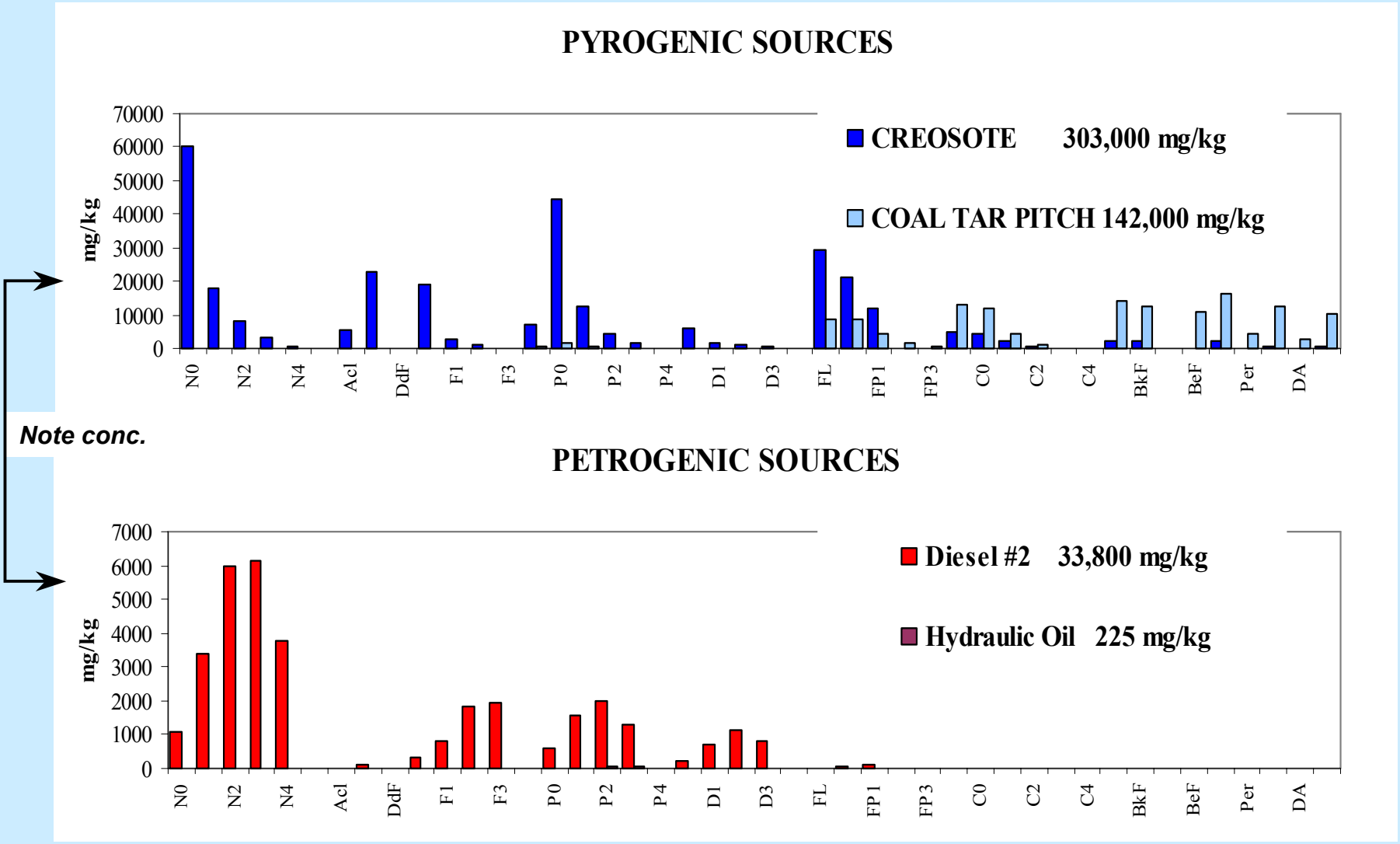
- **Pyrogenic**
  - High concentrations
  - Parent PAH dominant
  - 4- to 6-ring abundant
  - *Examples: combustion soot, carbonization-derived tars, creosote, pitch, etc.*
- **Petrogenic**
  - Low concentrations
  - Alkyl PAH dominant
  - 2- to 4-ring abundant
  - *Examples: petroleum products, crude oil*



Typical chrysene "fingerprints" in **pyrogenic** and **petrogenic** material

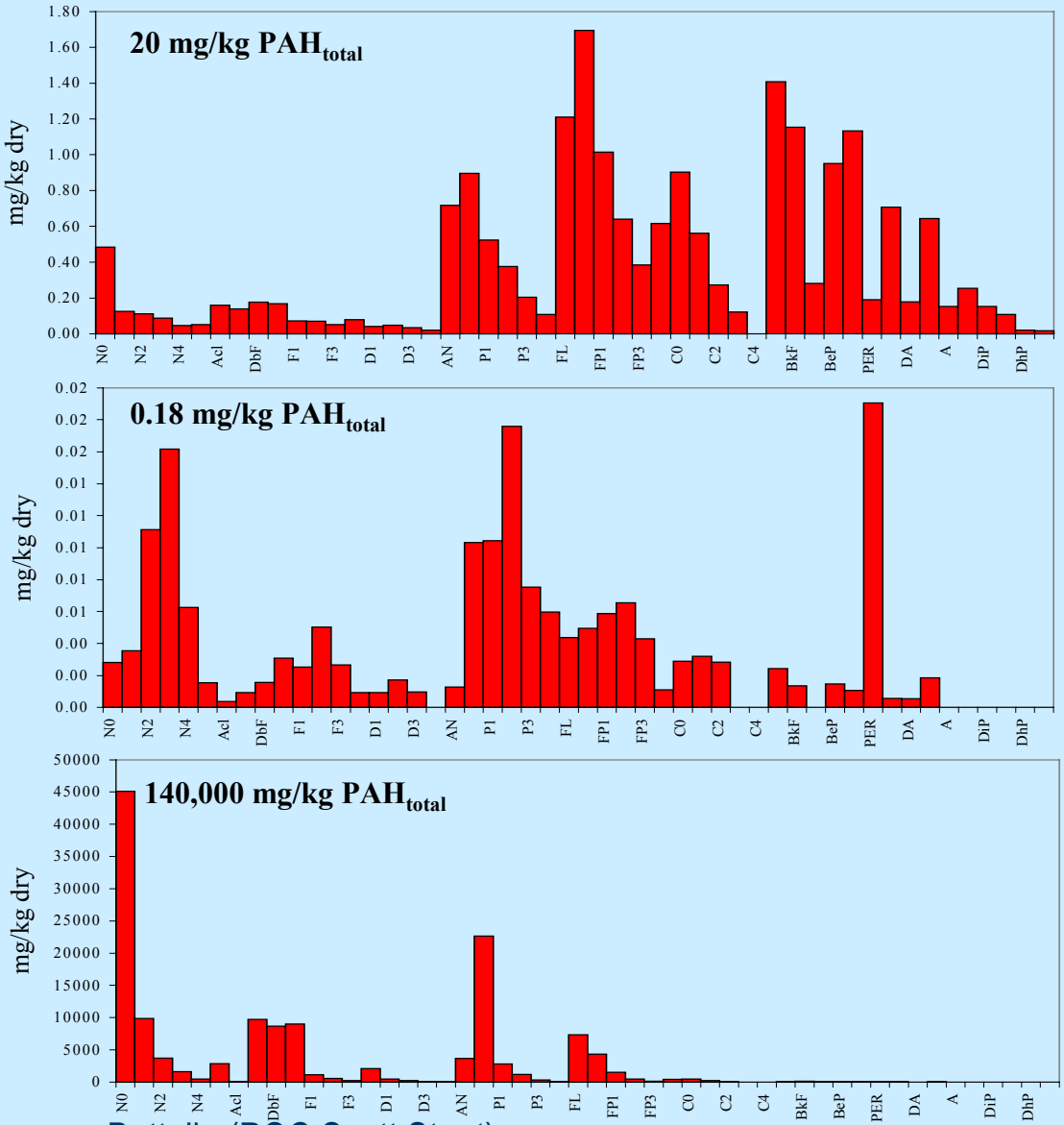
Source: Battelle (POC Scott Stout)

PAH Example



Source: Battelle (POC Scott Stout)

PAH Example



A Urban Runoff
- 4- to 6-ring PAH dom.
- 10-20 mg/kg$_{dry}$

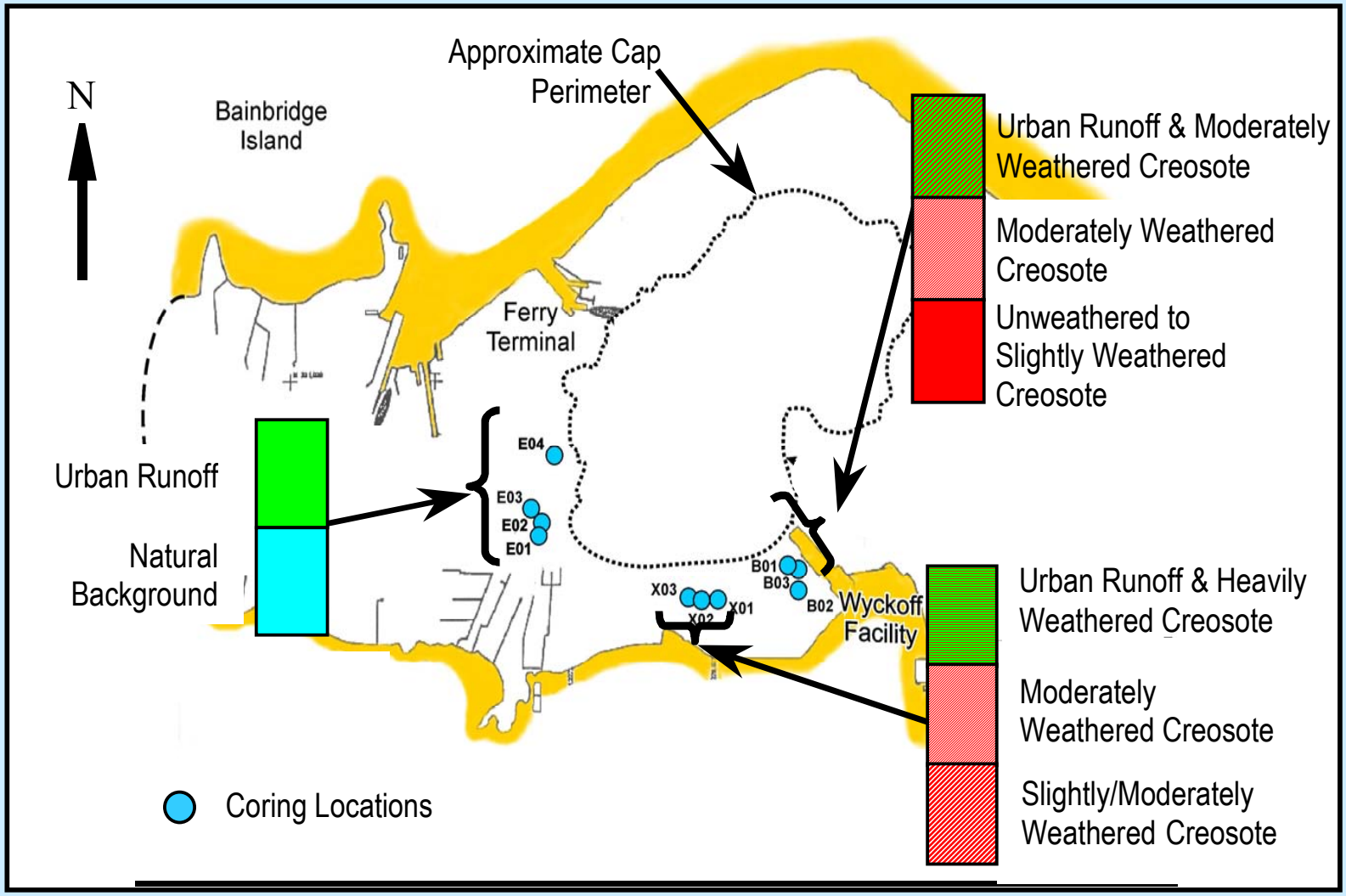
B Natural Background
- Perylene, 1,7-DMPhen
- < 1 mg/kg$_{dry}$

C Creosote
- 2- to 4-ring, parent PAH
- 1000-140,000 mg/kg$_{dry}$

Source: Battelle (POC Scott Stout)

PAH Example

Wyckoff/Eagle Harbor Forensics Case Study



Source: Brenner, et.al, 2002

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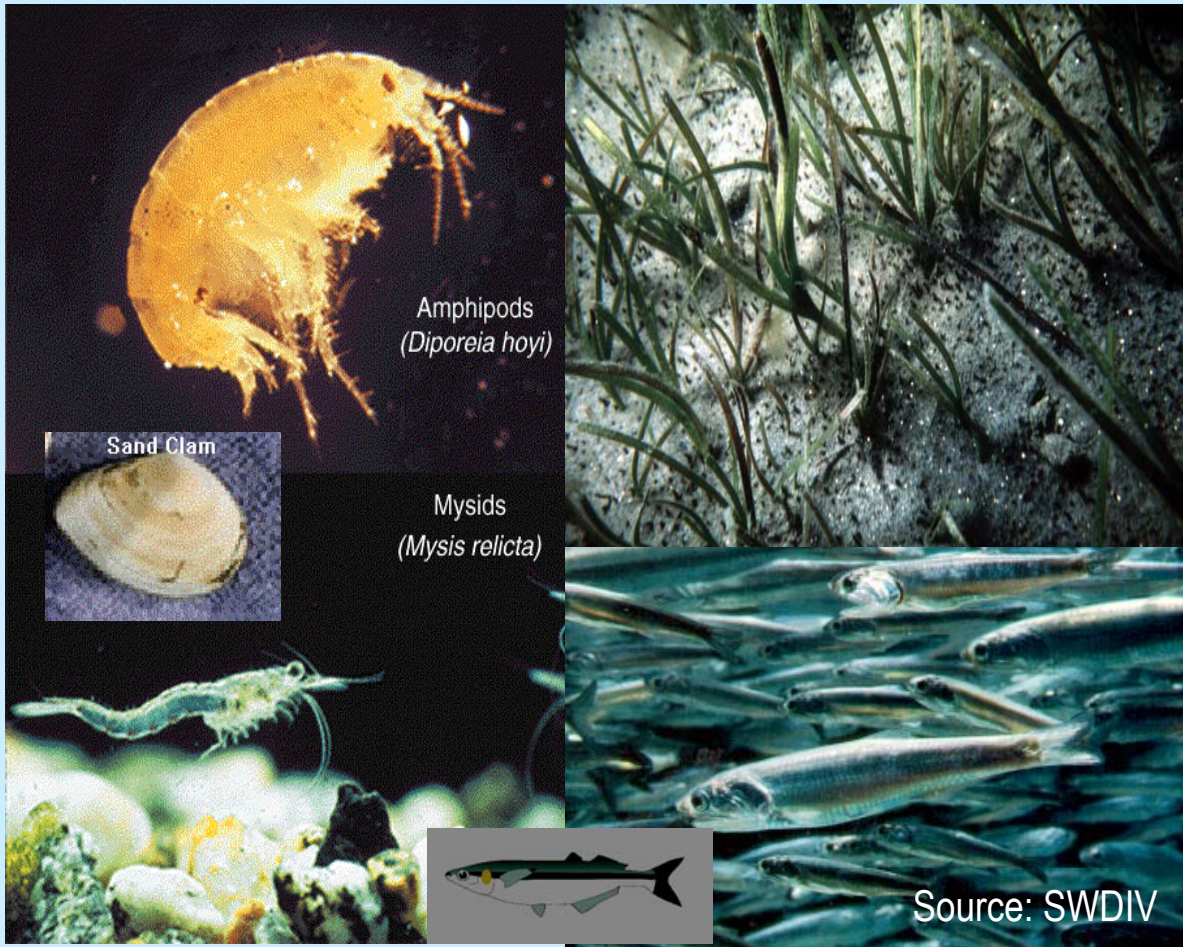
Toxicity

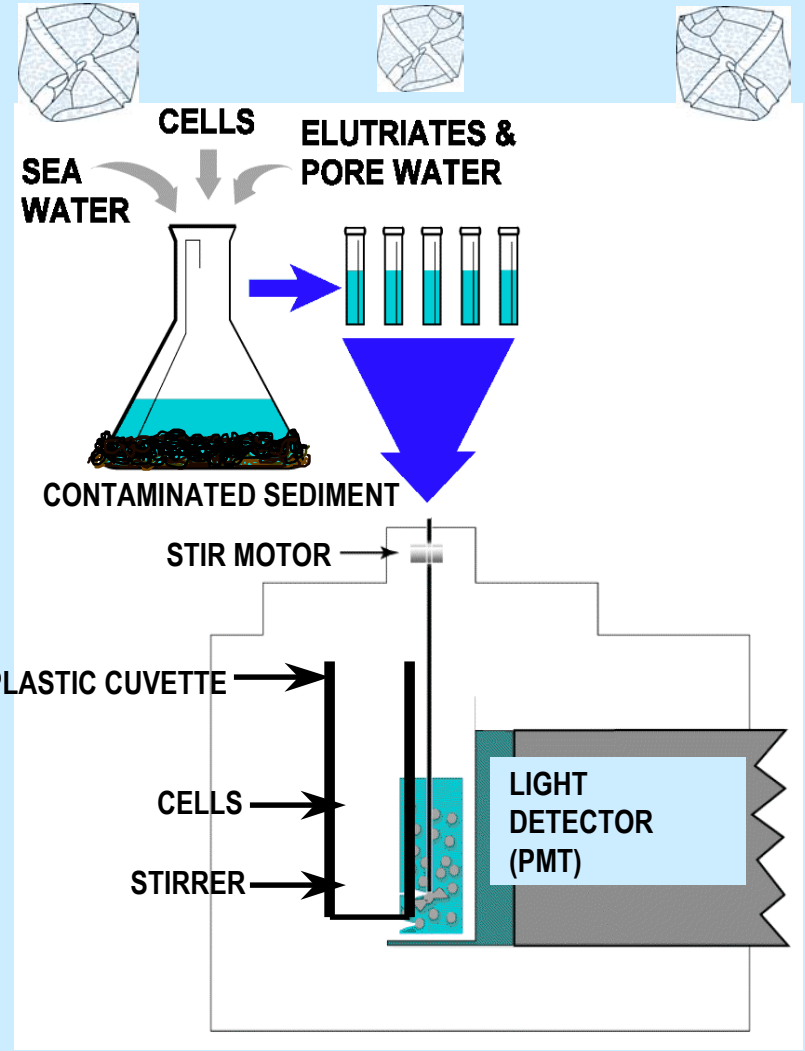
- Benthic bioassays are conducted to determine the potential impact of site media (e.g., whole sediment, porewater) on resident organisms
- Appropriate test species, route of exposure, and endpoint/mode should be selected to represent the sensitive infaunal or epibenthic organisms found in the vicinity of the site
- For use in ecological risk assessments, test sediments should be collected concurrently with physical and chemical samples

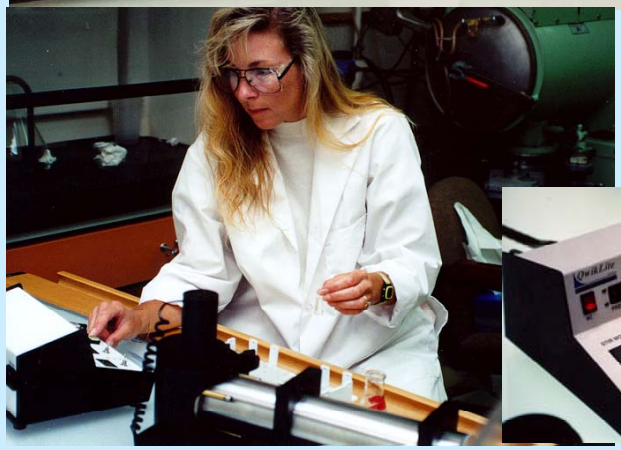
Toxicity

- Standardized toxicity tests of bedded sediments are the primary means of assessing sediment toxicity
- Types of tests typically acute and/or chronic
- Example endpoints:
  - Survival
  - Growth
  - Development
  - Reproduction
  - Fecundity
  - Reburial
  - Biomass
  - Bioaccumulation



Screening Example: QwikSed System





Source: SSC San Diego (POC Dr. Dave Lapota)

Bioaccumulation

- Some COCs may not be toxic to test organisms, but can potentially bioaccumulate in the food web
  - Bioaccumulation studies should be limited to those COCs that are known to bioaccumulate
- Studies include laboratory and field methods
  - Standard laboratory methods modified with fewer replicates but greater aerial extent
  - In situ studies using animals deployed in cages may produce cost savings and better data than standard laboratory tests
  - In either case, test species should produce sufficient tissue for chemical analysis and share common exposure routes with assessment endpoint species

Benthic Community Analysis

- Can provide an additional line-of-evidence for ERAs
  - Common attributes include species diversity, abundance, biomass, and key indicator species abundance
- However, benthic community studies have several drawbacks:
  - Can be long-term, costly, and inconclusive
  - Can be impacted by potential confounding factors
- Use only when COC and confounding impacts are discernible:
  - Use experienced benthic ecologist
  - Use suitable reference site
  - Use standardized collection and taxonomic methods

Source: Dr. Joe Germano, EVA

Biological Characterization Insights

- Test organisms should be representative of sensitive infaunal or epibenthic species found at the site
- Test methods should address factors that potentially confound bioassay results (e.g., ammonia & sulfide levels, grain size effects, low dissolved oxygen)
  - http://web.ead.anl.gov/ecorisk/issue/pdf/confound.pdf
- Tests should include several endpoints and species (e.g., acute test using adult life stage; development test [chronic] using larval life stage)
- Test sediments should be collected concurrently with physical and chemical samples

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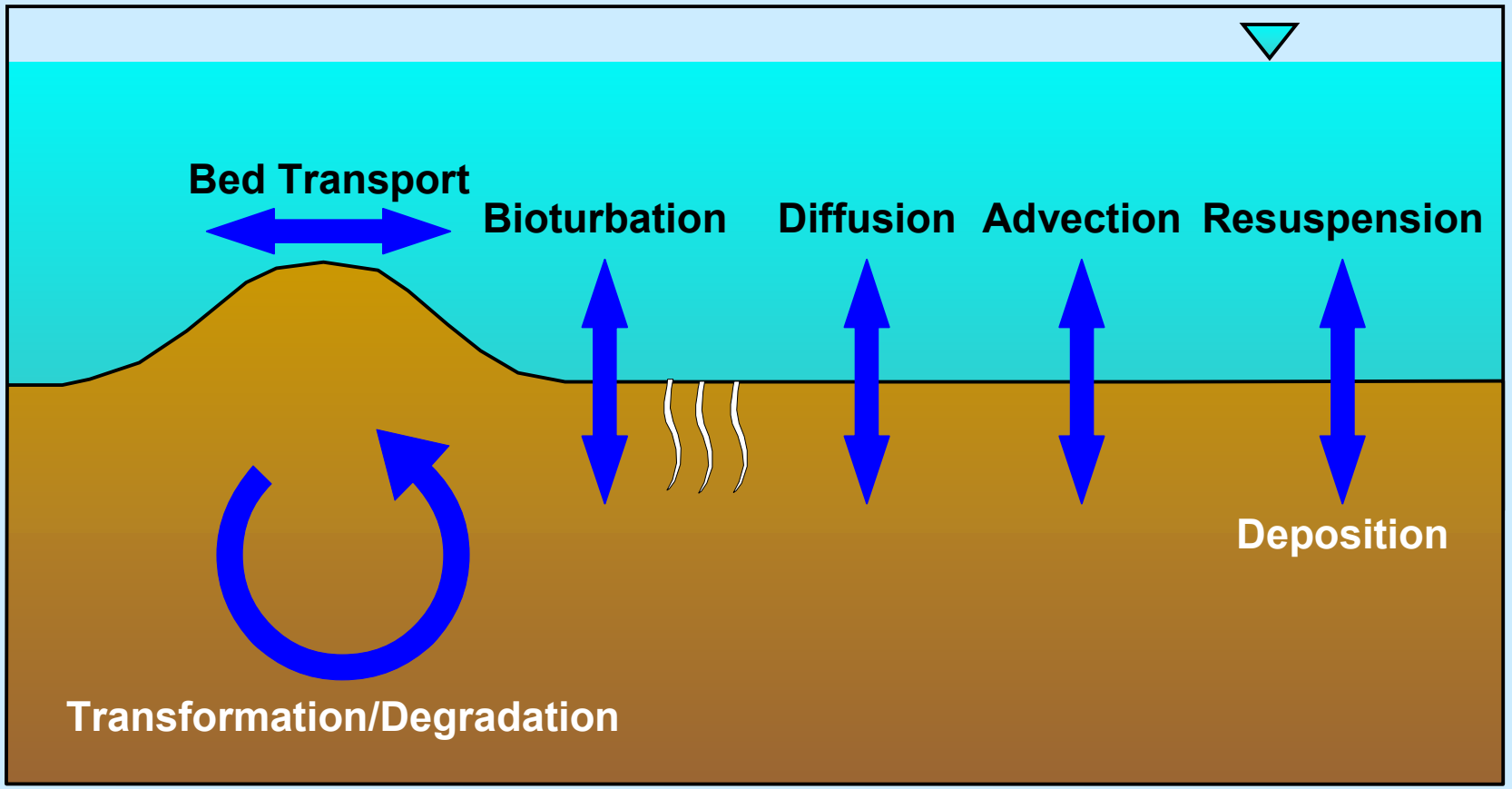
Contaminant Fate and Transport

- Fate and transport refers to the processes responsible for movement of contaminants and the media (matrices) in which they reside
- Fate and transport mechanisms support site characterization, help define the conceptual site model for ecological risk assessment, and influence selection of remedial alternatives
- Evaluations of fate and transport should address primary and secondary sources and exposure routes required to complete a conceptual site model and to evaluate the impact of remedial alternatives
  - Cursory to complex depending on evidence of mobility and impact on remedial alternative selection

Contaminant Fate and Transport

- Contaminants can potentially be distributed far from their original source via hydrodynamic processes
- Several other pathways exist and influence fate and transport to varying degrees
- An understanding of the regional context of a sediment site is important for both assessment and remedial decisions

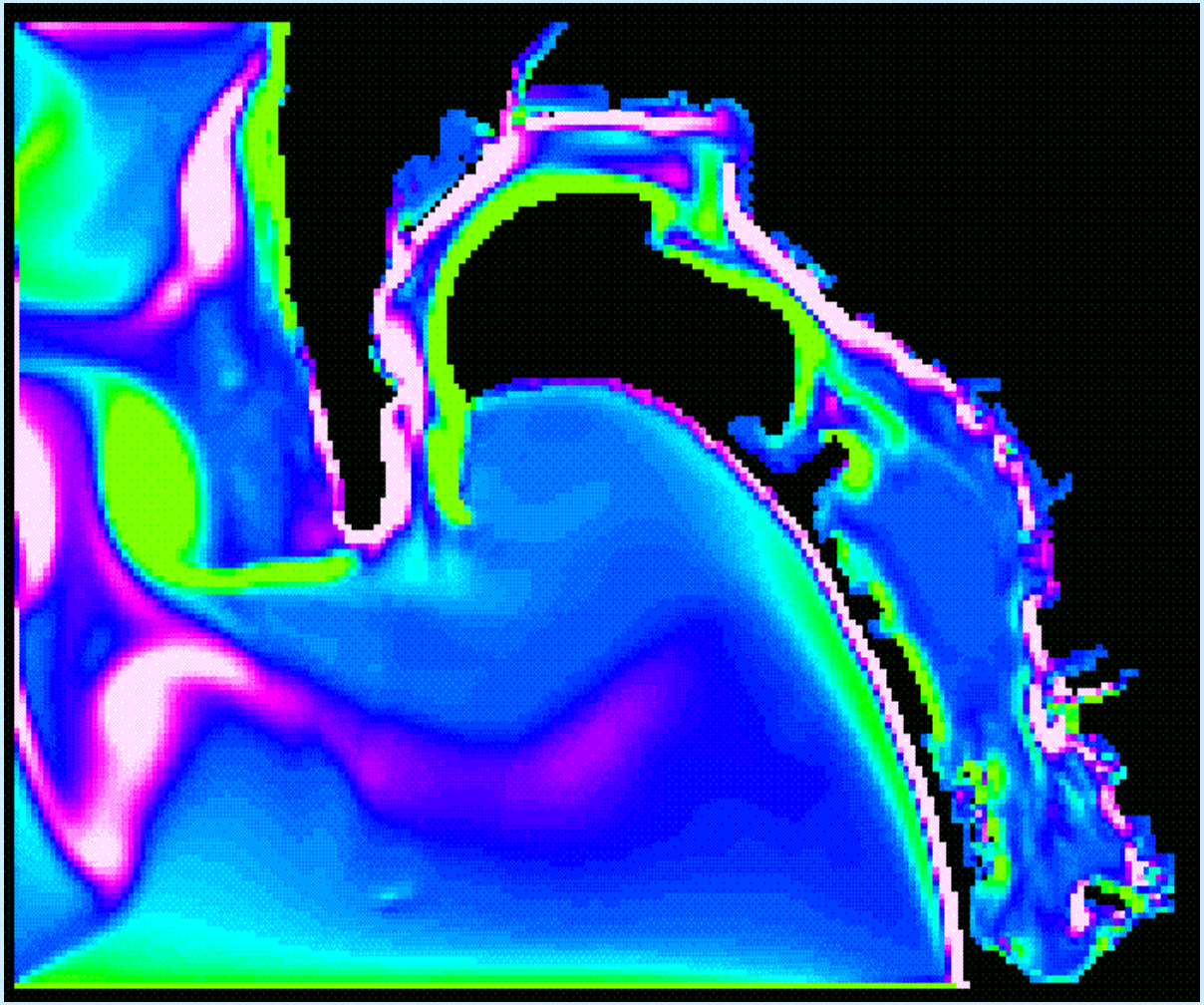
Examples of Fate and Transport Pathways



From Reible, D and Thibideaux, L (1999) "Using Natural Processes to Define Exposure From Sediments" Contaminated Sediment Management Technical Papers, http://www.smwg.org/index.htm.

Example: Sediment Contaminant Dispersal and Fate Modeling

- Model dispersal and fate of size-specific sediment fractions and associated contaminant load to assess environmental impact
- Dispersal arises from dredging, ship propeller wash and current erosion



Mixing (vorticity/turbulence scale) in San Diego Bay

Source: SSC San Diego (POC Dr. P.F. Wang)

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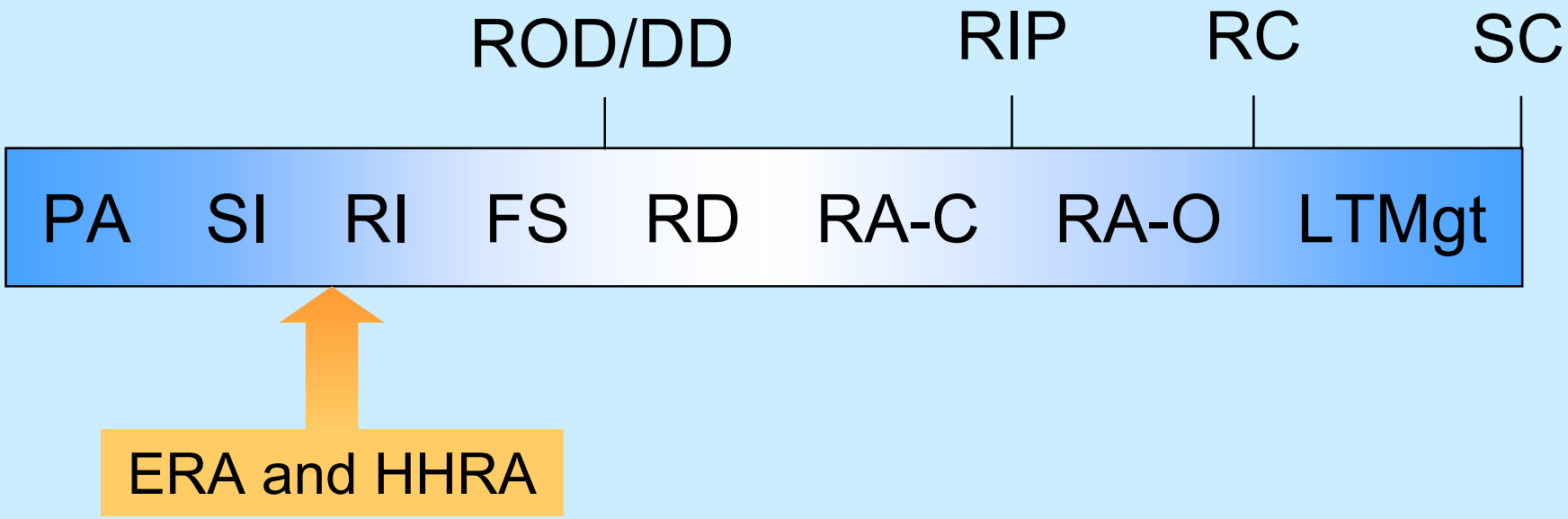
  - Human Health Risk Assessment (HHRA)
  - Sediment Remedial Alternative Evaluations
- References and POCs

IR Process



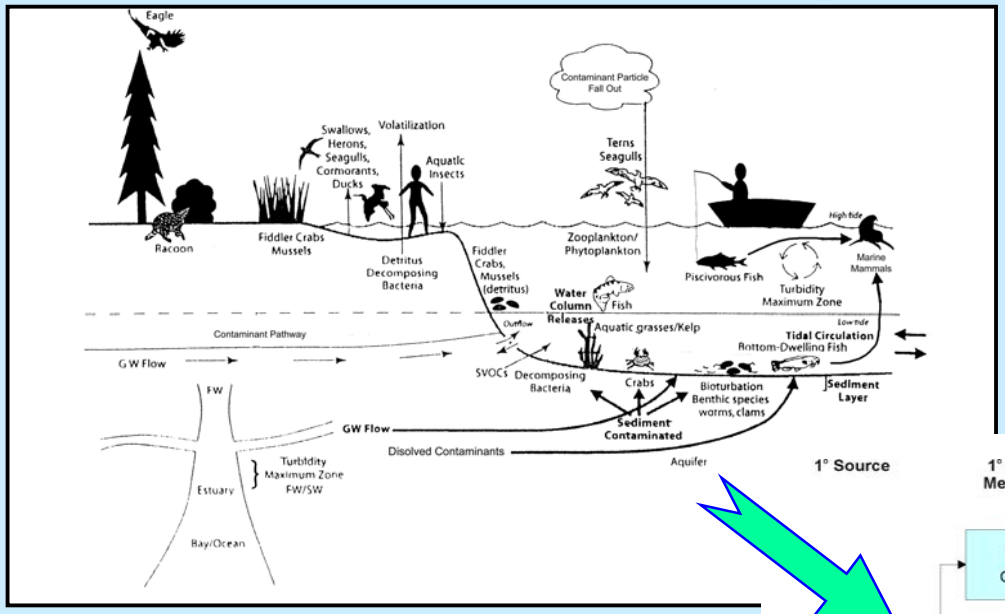
Ecological Risk Assessment

- Sediment Guide Covers Basic Components of an Ecological Risk Assessment
  - Preliminary planning and building the team
    - Data collection considerations
    - Technical personnel requirements
- Sediment-specific issues in screening and baseline ecological risk assessment tiers/steps
  - Tier 1 – U.S. EPA Steps 1 and 2
  - Tier 2 – U.S. EPA Steps 3 through 7
  - Risk Management (U.S. EPA Step 8) is incorporated throughout the process

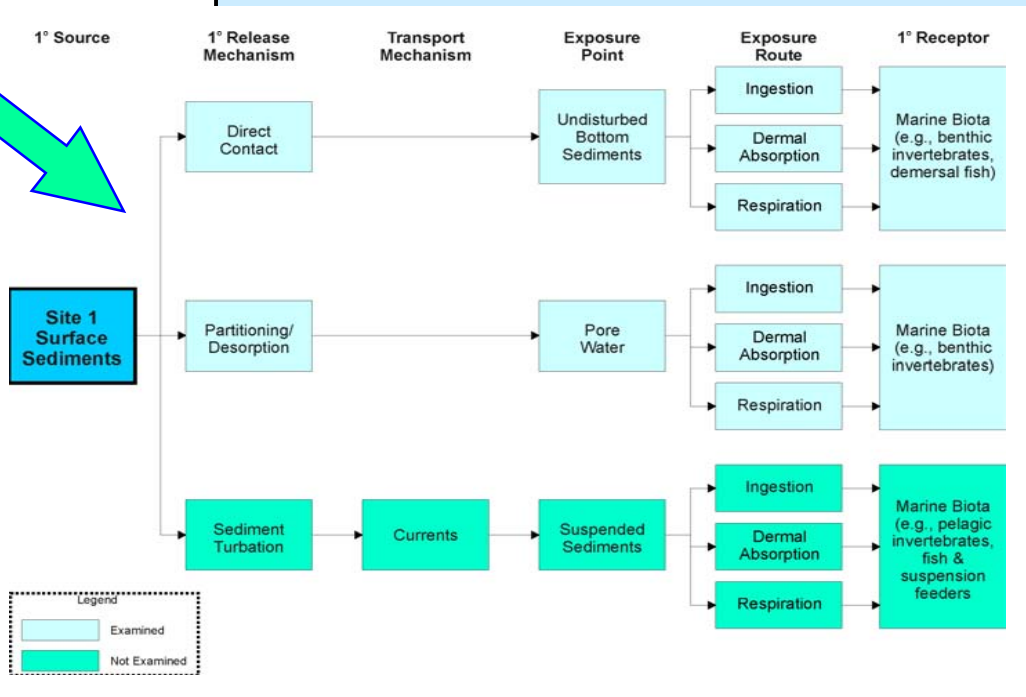
Ecological Risk Assessment

- ERA section includes discussion on:
  - Developing a preliminary problem formulation, CSM, and exposure pathways
  - Using appropriate aquatic benchmarks values
  - Develop planning matrix in SRA that carries through BERA
  - Refining COPCs, CSM, and risk hypothesis
  - Agreeing on risk questions, lines-of-evidence and decision matrix in BERA
  - Establishing appropriate complexity, suitability and feasibility of field sampling design
  - Use rapid characterization and high-quality laboratory analytics for cost effective, usable data

Generic to Site Specific Sediment CSM



Source: U.S. EPA



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Example Planning Matrix

Receptor Class and Specific Receptors	Assessment Endpoints	Risk Questions	Surrogate Species or Community	Measurement Endpoints	Uncertainties	Notes

Source: Neptune and Co.

Example Decision Matrix

Example of Decision Rules used at a West Coast Navy Sediment Site

Decision Rule	Chemical Exceedances	Toxicity	Significant Bioaccumulation	Possible Actions/Possible Causes
1	+	+	+	Evaluate absolute risk/ Conclusive evidence for COPC–induced degradation
2	+	+	–	Evaluate absolute risk of non–bioaccumulating COPCs/ Conclusive evidence for COPC–induced degradation; unlikely due to persistent bioaccumulative substances
3	+	–	–	No further action/ COPCs not sufficiently bioavailable to cause effects; however, possible future monitoring if COPCs can become bioavailable through environmental changes (e.g., pH, grain size, organic loading)
4	–	+	–	Re–evaluate study design; determine cause of toxicity/ Possibly due to change in bioavailability through sediment handling. Alternatively due to an unknown chemicals (less likely)
5	+	–	+	Evaluate absolute risk in higher trophic levels/ Although bioavailable, COPCs are not affecting the system; potential food web effects
6	–	–	–	No further action/ Conclusive evidence for ecologically unimpaired site

[1] =adopted from sediment ERA at NAS San Diego Site 1 (SPAWAR 1999).

Source: SWDIV

Overview

- Sediment Issues and Ecosystem Background
- Definitions
- CNO Sediment Policy
- Introduction to NAVFAC Sediment Implementation Guide
- Sediment Site Characterization
- Basics of Remaining Sediment Guide
  - Ecological Risk Assessment (ERA)
  - Human Health Risk Assessment (HHRA)
  - Sediment Remedial Alternative Evaluations
- References and POCs

Human Health Risk Assessment

- Sediment Guide Covers Basic Components of an HHRA
  - Data evaluation
  - Exposure assessment
  - Toxicity assessment
  - Risk characterization
- Sediment-Specific Issues using the Navy's Tiered Approach to Human Health Risk Assessment
  - Tier 1 SRAs (Tier 1A and Tier 1B)
  - Study proceeds to Tier 2 if unacceptable risks to human health are determined

Human Health Risk Assessment (cont.)

- HHRA section includes discussion on:
  - CSMs
  - Fish and shellfish consumption
  - Dermal contact
  - Incidental ingestion
  - Evaluating lead exposures
  - Cumulative and aggregate risk, and
  - Evaluating fish tissue residues, etc.

Summary of Sediment Risk Assessment Sections

- Always use the right technical expertise
- Identify sources and develop a WCSD
- Construct initial problem formulation and CSM and refine during the process using a planning matrix as a tool
- Use RSC tools combined with high-quality laboratory analytics to ensure cost-effective, usable data
- Verify feasibility and suitability of sampling design
- Use decision criteria and site-specific information to determine risk and cleanup goals, if required
- Obtain source control prior to remedial activities, and
- Document agreements and discrepancies along the way

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Remedial Alternative Evaluation

- Planning considerations
  - FS-related data, source identification/control, multiple PRPs, consideration of anticipated future land use, identification of potential applicable or relevant and appropriate requirements (ARARs)
- Determining extent and volume of sediment to be remediated (remediation goals, cleanup levels)
  - Contaminant- and site-specific remediation goals and cleanup levels
  - Consideration of contamination at depth

Remedial Alternative Evaluation (cont.)

- Remedial option selection
  - Monitored natural recovery
  - In situ capping
  - Dredging considerations
  - Sediment disposal and treatment options
  - Beneficial reuse
  - In situ vs. removal responses
  - Risks inherent in each remedial alternative
  - Table of existing and innovative remedial technologies
- Monitoring considerations
  - Before, during, and after remedial actions

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Website References

- NAVFAC Guidance for Ecological Risk Assessment (includes Issue Papers): http://web.ead.anl.gov/ecorisk/
- U.S. EPA General Website for for Laws, Regulations, Programs etc.: http://www.epa.gov/epahome/
- U.S. EPA General Superfund Website: http://www.epa.gov/oerrpage/superfund/index.htm
- U.S. EPA Guidance for Ecological and Human Health Risk Assessment: http://www.epa.gov/oerrpage/superfund/programs/risk/toolrad.htm
- U.S. EPA Guidance for Feasibility Studies and Remedial Alternative Evaluation: http://www.epa.gov/oerrpage/superfund/whatissf/sfprocess/rifs.htm
- U.S. EPA Technology Innovation Office: http://www.clu-in.org/
- Contaminated Sediment Management Strategy document: http://www.epa.gov/OST/cs/stratndx.html

Website References

- Regulatory Searches: http://regscreen.nfesc.navy.mil/htm/search.htm
- Sediment Research Website for Project Summaries, Technical Reports and Information on Sediments: http://www.sediments.org/
- Sediment Management Working Group. Advocates Risk-based Cleanups; Information on Natural Attenuation: http://www.smwg.org/
- State of Washington Department of Ecology Internet Site on Sediments: http://www.ecy.wa.gov/programs/tcp/smu/sediment.html
- Major Contaminated Sediments Sites Database that includes cleanup standards and project costs. A joint effort of the GE Co., Applied Environmental Management, Inc., and Blasland, Bouck & Lee, Inc.: http://www.hudsonvoice.com/mcss/index.html
- U.S. Geological Survey site; Wetlands creation in the San Francisco Estuary: http://sfbay.wr.usgs.gov/access/saltponds/index.html
- Division of Environmental Chemistry Home Page, American Chemical Society: http://www.acs-envchem.duq.edu/

Information on Aquatic Sample Collection, Field Quality Control, and Equipment Type

- State of Washington – Dept. of Ecology. Marine reference applicable to any water body for sediment and water sampling; fish & benthic invertebrate collection; vessel positioning; and field quality control: http://www.wa.gov/puget_sound/Publications/protocols/protocol.html
- State of Wisconsin – Dept. of Natural Resources. Freshwater reference for sediment sampling, equipment, safety & field quality control: http://www.dnr.state.wi.us/org/water/wm/wqs/sediment/sampling/table.htm
- U.S. Geological Survey (USGS). Applicable to any water body; a course on sediment vibrocore sampling: http://www.dnr.state.wi.us/org/water/wm/wqs/sediment/sampling/701_4.HTM
- Government of British Columbia, Resources Inventory Committee. River and stream bottom sampling reference for sediment sampling, equipment, quality control: http://www.for.gov.bc.ca/ric/pubs/aquatic/lake-stream/index.htm - a
- San Francisco Estuary Institute (SFEI). Estuarine and marine reference applicable to any water body on sediment, porewater, water column, benthic invertebrate sampling; CTD monitoring; equipment type & use; quality control; remote sensing; vessel safety: http://www.sfei.org/rmp/docs/fom_4.html
- U.S. EPA, Office of Water. Methods for Collection, Storage, and Manipulation of Sediments for Chemical and Toxicological Analyses: Technical Manual.